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MARCH 2012 / Vol. 20 / No. 2

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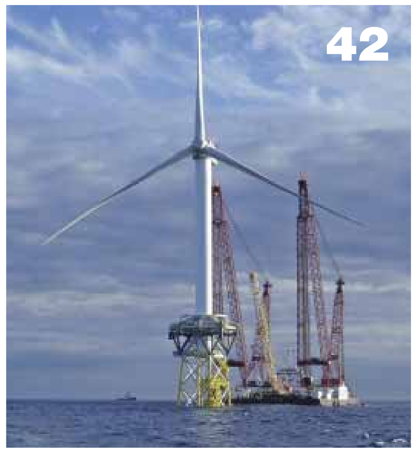

COLUMNS

DEPARTMENTS

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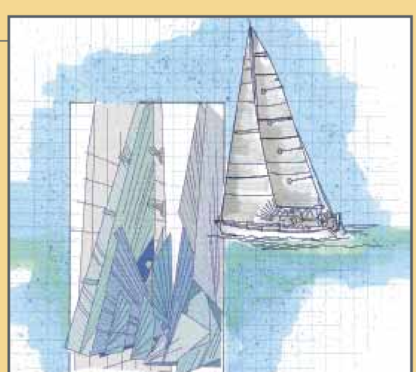
FOCUS ON DESIGN



ON THE COVER

Shown in action during the 2011-2012 Volvo Ocean Race, this *PUMA* 70-ft carbon-fiber composite racing yacht caught wind with monolithic composite sails fabricated via automated tape laying by North Sails' (Minden, Nev.) 3D*i* division. For more on the unique process and materials used to form the sail structures, see p. 62.

Source: North 3D*i*

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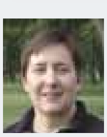

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FROM THE EDITOR

jeff@compositesworld.com

In our daily haste to progress and advance the technologies that shape the composites industry, it's easy to get caught up in the constant quest to look ahead. In doing so, we forget, on occasion, to look behind at the history that shaped this industry — both in large and small measure. Indeed, is vitally important to take time to study and appreciate where we've been and the forces that have led us to this point. Those forces often are *people*. And in the relatively small composites community, such people are not only abundant, but very often familiar to many of us as well.

> When industry icons pass, it's appropriate that we appreciate who they were and what they contributed to the composites world.

So, when industry icons pass, it's appropriate that we take a moment to appreciate who they were and what they meant to composites. Such a passing occurred on Feb. 14 as *HPC* was going to press; we got word that day that composites industry veteran Bill Benjamin had passed away following several years of declining health.

William P. Benjamin was well known to many in the composites industry as a champion for new materials and processes during his nearly 50-year career. The author of several books, Bill held a patent on induction welding of thermoplastic composites, and he served as an advisor to several colleges and universities.

In 1978, The Boeing Co. recognized the need to automate its composites processing if composites were ever to become cost-effective. Bill was selected to head Boeing's first Composites Automation Group, and was successful in attracting, in his words, "a dynamic team, with some of the best creative minds I've ever encountered." That group subsequently posted many "firsts," including the development and implementation of contour tape layup, originating the concept of fiber placement, developing pultrusion technology for epoxy prepreg systems, and conceiving and developing an automated channel-forming machine.

Bill went on to establish *Composites Market Reports*, an in-depth newsletter and intelligence report for the industry that became a must-read for anyone involved in aerospace composites. Benjamin also was a contributor to *High-Performance Composites* magazine over the years.

While we mourn the passing of Bill and appreciate his contributions, it should be noted that his legacy persists: Chris Red, his stepson, who took up the *Composites Market Reports* mantle as Bill's health declined, has become, in his own right, a vital contributor to the composites industry as a market researcher and industry analyst.

As the composites industry continues to mature, it's certain that we will see the passing of others who, like Bill Benjamin, have attained well-deserved stature. As a publication of record for composites, we here at *HPC* believe it's vital that we take the time to remember the men and women who have given so much of their time, money, effort and intellect to propel this community to this point.

I'd like to encourage you to help us recognize such contributions *before* those who make them are no longer with us. Please alert any of us here at *HPC* to any milestones important to your company or organization. This includes achievements, accomplishments, discoveries and breakthroughs of all kinds, whether done by an individual or a group. You can be a vital part of helping make sure the entire industry recognizes and appreciates the role that we all play. If you want to get in touch, the best way to communicate with the *HPC* staff is via e-mail at pr@compositesworld.com, or you can contact me directly at jeff@compositesworld.com.

Jeff Sloan

MARKET TRENDS

COMPOSITES BUSINESS OUTLOOK: CONSOLIDATION ON THE HORIZON

Michael Del Pero is an investment banker based in Los Angeles, Calif., with expertise in the plastics, composites and advanced materials industries. A regular contributor to industry publications, including *High-Performance Composites* and *Composites Technology*, he also chaired the CompositesWorld Investment Forum in 2010 and 2011. Del Pero has advised dozens of companies in the composites and advanced materials sectors in areas involving mergers, acquisitions, capitalization, and strategic planning. He holds a BA in economic sociology, with a specialization in finance and business administration, from UCLA. He holds FINRA series 7, 63, 65 and 79 licenses. He can be reached at (310) 995-1831.

As we kicked off the New Year, we reflected on a composites industry that is once again at a crossroad. We observed that the growing demand for materials innovation and technology advancement of the past several years has poised the industry for momentous growth in an expanding array of applications and end-markets. Ironically, the same driver behind the industry's growth and distinction in those years has resulted in one of the greatest challenges the industry will face as it moves forward — an unprecedented level of fragmentation.

> More than ever, customers are looking to their suppliers for a complete solution.

As it stands, there are currently more than 400 processors and manufacturers in the carbon fiber-reinforced plastic segment alone that each generate less than $20 million (USD) in annual sales. Granted, to many in the industry, this might seem like a relatively sizable revenue base. But if this figure is compared to annual sales numbers in most other industrial segments and end-markets, it is clear that a $20 million company is very small. A similar degree of fragmentation also can be found throughout the rest of the composites industry (suppliers of fibers and resins, equipment and ancillary products). Now, if we contrast the diverse array of specialty companies that comprise the lower end of the market to those at the top end of the market, where there are 8 to 10 large industry players with annual revenues well in excess of $100 million, we see an industry that is primed for consolidation.

Before going any further, it should be noted that consolidation need not be perceived as inevitably negative. In fact, consolidation that is entered into appropriately and executed properly can introduce quite an additive element to a company's expansion strategy and provide ample personal and professional growth opportunities for its employees. There are two ways to look at consolidation. On one hand, it is seen as a means of cutting costs to preserve profit margins. In a mature and established industry that does not have high growth characteristics, consolidation is an effective strategy for vertical integration and/or reduction of overhead expenses. On the other hand, in a rapidly growing, technology-rich industry where profit margins tend to be healthy, consolidation efforts are more typically geared toward building scale, adding capabilities, diversifying end-markets and/or leveraging organizational infrastructure to help professionalize a growing business. Obviously, the composites industry fits into the latter category.

Setting the demographics of the industry aside for a moment, the composites market is gravitating in the direction of greater *strategic definition*. More than ever, customers are looking to their suppliers for a complete solution as opposed to simply a product or service. In response, suppliers are aspiring to the role of *integrated solution provider*, which can be defined as a company that is capable of offering everything from design, materials science and applications engineering all the way through manufacturing and technical support. Subsequently, there is a significant growth opportunity for integrated solution providers because they can differentiate themselves from their competitors *if* they have the capabilities to deliver a larger portion of the supply and value chain.

I see a small but growing number of manufacturers and suppliers taking heed of this trend and proactively seeking ways to deliver an increasing portion of the value chain. This intimate community of small- to medium-size composites players has identified the evolution of the market, and each is executing a strategy around it. Strategies include raising external capital to fund growth and expansion as well as developing strategic acquisition efforts to add specialized capabilities to existing core service offerings.

The result of these actions will be a number of streamlined industry players jockeying to fill the void in the market between the masses of small niche suppliers and the handful of large corporations. These middle companies will be very well positioned for explosive growth and profitability as they move forward. We expect this trend to be particularly relevant outside the aerospace sector in emerging markets. An integrated provider's ability to deliver a comprehensive solution will be critical to easing and accelerating a new customer's journey along what will be a very steep new-technology learning curve. This is particularly true in markets where composites technology may not have the same legacy of evolutionary development we've seen in aerospace.

This shifting landscape creates an attractive opportunity for a strategic acquirer to string together several technology-rich and synergistic assets, ➲

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creating a fully integrated and scalable operation that can really make some noise in the industry. Over the past year, we've seen glimpses of this trend coming from large nontraditional strategic acquirers that have acknowledged the need to have a meaningful foothold in the composites industry.

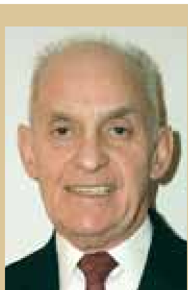
Similarly, the financial community continues to take notice of some growth opportunities in the advanced materials sectors, and we expect to see technology-focused private equity or venture capital groups make a run at this same strategy. Such investors specifically target sectors with above-average growth profiles that enable them to deliver above-average returns for their investors. And in an economy struggling to regain momentum, the composites industry's growth rate — projected to reach double digits over the next five years — presents a very compelling investment thesis.

Supporting the list of strategic rationales for deal making in the industry is the fact that credit markets are aggressively seeking opportunities to put capital to work. Last year was a record year for many banks and lenders. Consequently many of these institutions have lofty expectations as they begin to build on that momentum, moving into 2012.

When we put all of this together, we see the building blocks for healthy transaction activity going into an election year and ahead of likely increases in capital gains taxes in 2013. In fact, with corporate valuation levels peaking, abundant available capital and easing credit conditions, 2012 has all the potential to be a boom year for mergers and acquisitions and financing transactions across the board. ■

TESTING TECH

TESTING THE DAMAGE TOLERANCE OF COMPOSITE MATERIALS



Dr. Donald F. Adams is the president of Wyoming Test Fixtures Inc. (Salt Lake City, Utah). He holds a BS and an MS in mechanical engineering and a Ph.D in theoretical and applied mechanics. Following a total of 12 years with Northrop Aircraft Corp., the Aeronutronic Div. of Ford Motor Co., and the Rand Corp., he joined the University of Wyoming, directing its Composite Materials Research Group for 27 years before retiring from that post in 1999. Dr. Adams continues to write, teach and serve with numerous industry groups, including the test methods committees of ASTM and the *Composite Materials Handbook 17*.

In the early 1980s, the limited damage resistance/tolerance of relatively brittle carbon/epoxy composite materials that had been available up to that time spurred development of toughened epoxies, bismaleimides, polyimides and high-temperature thermoplastics, such as PEEK, PPS and PAS. These materials enabled designers to extend composites to new applications while considering "the effects of defects," which became a new catchphrase. But these enhanced properties in the new materials necessitated the development of corresponding new tests to quantify their *damage resistance* and *damage tolerance*.

Two categories of damage-tolerance test methods gained particular attention: *open-hole* and *compression-after-impact*. Each was developed somewhat independently in different forms by a number of industry and government groups. By 1990, several detailed approaches, and corresponding test-fixture configurations, had been published but the level of use in the composites community remained limited.

It was the well-defined and oft-quoted seminal publication by The Boeing Co. (Seattle, Wash.), "Advanced Composite Compression Tests,"[1] that had the greatest influence. First published in 1982, it led to a number of subsequent Boeing documents, to the Suppliers of Advanced Composite Materials Assn.'s (SACMA) Recommended Methods SRM 3-88 and SRM 2-88, and to NASA Reference Publication 1092. Eventually, two new ASTM standards resulted. Since then, several European and ISO standards also have been written, following the same general procedures.

It was the publication of the ASTM standards that firmly established damage tolerance testing as a desired element in the characterization of composite materials. The first of the two is ASTM D6484[2], "Open-Hole Compressive Strength of Polymer Matrix Composite Laminates." The 300-mm/12-inch long, 36-mm/1.5-inch wide specimen contains a centrally located 6-mm/0.25-inch diameter hole, which is assumed to be an idealized defect, amenable to a corresponding stress analysis of the effect of this "defect" on structural performance. But actual structures also have deliberately induced holes and cutouts that provide internal access or accommodate fasteners. Therefore, this standard serves a dual role, and its use increased rapidly as it has become more widely known. Although a quasi-isotropic $[0/\pm45/90]_{ns}$ laminate is typically used, other layup configurations can be specified as well, if they are appropriate to the design application.

The Boeing/ASTM test fixture is shown in Fig. 1. Because the compression specimen is so long, the primary function of the test fixture is to prevent the specimen from buckling by constraining it between the fixture's flat plates. As originally conceived by Boeing, the fixture is gripped between large wedge grips, and the load is induced into the specimen by shear forces between the fixture and the specimen. But because the ends of the specimen and fixture are flush, the ASTM standard also permits direct end loading.

A similar test method, developed by the Northrop Corp.[3] (Hawthorne, Calif.), uses a 76-mm/3-inch long, 25-mm/1-inch wide end-loaded specimen, also with a 6-mm/0.25-inch diameter hole and a somewhat different fixture configuration. Although it has been demonstrated that this alternate configuration yields similar results yet *conserves* specimen material, it has not been adopted by any standards group and, therefore, is not widely used.[4]

A carefully prepared round hole is relatively easy to replicate from specimen to specimen, but it may not be representative of the actual degradation of strength properties that can occur in a dam-

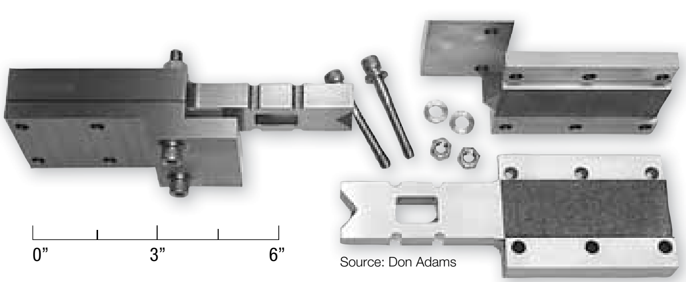


Fig. 1 ASTM D 6484 Open-Hole Compression test fixture.

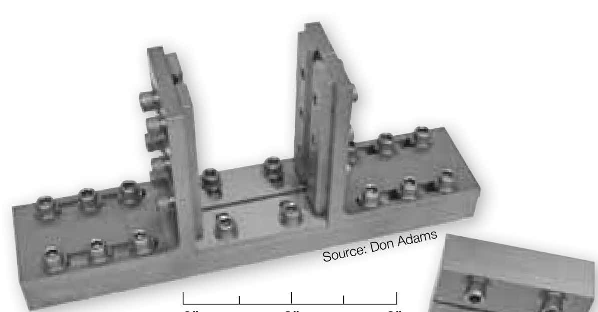


Fig. 2 ASTM D 7137 Compression-after-impact Compression test fixture.

aged structure. Damage often is induced by accidental impact and may be invisible, or barely visible, to the unaided eye.

To simulate such damage, the Compression After Impact (CAI) test was developed, now standardized as ASTM D7137.[5] Adapted from the original Boeing version, the quasi-isotropic specimen is 150 mm/6 inches long, 100 mm/4 inches wide and typically ~5 mm/~0.2 inches thick. After the specimen is subjected to a controlled impact-damage event, it is clamped over a rectangular hole in a baseplate and drop-weight impacted by a hemispherical-nosed tup that delivers a specified amount of energy, which typically induces visible but limited damage (see ASTM D7136).[6] Then the specimen is subjected to inplane compression in the fixture shown in Fig. 2 while it is supported along all four edges and uniformly loaded along its shorter edges. The two long edges are supported by "knife edges," and the supports along the short edges are actually flat surfaces, but the clamping forces are minimal.

An alternate CAI fixture was introduced by NASA[7] about the same time as the Boeing original, using a 254-mm/10-inch by 127-mm/5-inch specimen. Because it consumed more specimen material than the Boeing method and its fixture has no obviously superior technical features, NASA's method never gained much popularity, even though the specimen size could have been sized like Boeing's.

Much more recently, Airbus SAS (Toulouse, France) has introduced a modification of the Boeing fixture, using the same specimen size and employing edge-constraint geometry, but providing for the application of positive clamping force on all four edges via clamping screws.[8] Although this helps assure that positive contact is made with the specimen edges, the specimen's long sides are still "simply supported" by knife edges, and the clamping screws cannot provide enough rotational restraint to induce a "fixed" boundary condition on the short sides. Consequently, it is not obvious what technical benefit has been gained relative to the Boeing/ASTM fixture. That said, the Airbus fixture is gaining popularity, primarily among those who conduct testing for Airbus Industries.

No other damage tolerance test methods have been introduced in recent years, and none are on the horizon. Therefore, it is likely that the two existing Boeing/ASTM standards discussed here will continue to govern testing for some time to come. ■

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FROM THE PODIUM

LOOKING AHEAD TO NEXT-GEN AEROSTRUCTURES

Scott Stephenson is CompositesWorld's conference director. He has been involved with carbon fiber composites since 1983 when he started working for Fiber Materials Inc. (Biddeford, Maine), a leading manufacturer of carbon/carbon composites. Since 1997, Stephenson has organized conferences and published studies to provide industry executives with strategic information about, and analyses of, the advanced materials and technologies that drive innovative product development.

Although the Airbus A350 XWB and the Boeing 787 are new to the commercial aircraft market, the design and material choices for these planes are, by comparison, relatively old and very much a settled matter. And even if the first A350 XWB has yet to fly, it's not too soon to start thinking and wondering about the material and functionality demands of the next generation of commercial aircraft. More importantly, it's not too soon to wonder what role composites might play in those craft.

Bruno Beral, head of structure policy and development at Airbus SAS (Toulouse, France), was asked to look into the Airbus future with this question in mind. He spoke on that subject at CompositesWorld's 2011 Carbon Fiber conference, held in December, in Washington, D.C.

Beral began with a review of composites use throughout the Airbus family, dating back to the A300 aircraft in the early 1970s. This plane was less than 5 percent composites by weight, but it proved to be just the starting point for increased composites use in successive aircraft, including the A320, A340, A380 and, now, the A350 XWB, which is 52 percent composites.

Although the Boeing 787 and the A350 are of similar size and shape, many of the notable composite features of the Airbus craft differ significantly from those of the 787. Beral reported that, in contrast to the Boeing 787's full-barrel tapewound fuselage, the Airbus design is manufactured in four sections; each section features four independently manufactured curved panels, made with carbon fiber prepreg tapes and integrated stringers, which are subsequently assembled to form the barrel section. The longest fuselage panel section is 18m/59 ft long. Further, he reported, the use of a composite wing on the A350 saved 2.5 metric tonnes (5,512 lb) as compared to a metallic design.

Looking to the future, one thing Beral made clear is that, although carbon fiber made great strides on the A350, Airbus is being careful not to place all of its material eggs in either the composites *or* the metals basket. He emphasized that "no single material can do it all,"

> Airbus is being careful not to put all of its material eggs in one basket.

noting that Airbus likes to encourage competition between composites and metals, believing that such competition is healthy and produces the best aeroproducts. For that reason, all options are on the table.

That said, Beral and Airbus have specific goals and ideas driving the design and engineering of its next-generation commercial aircraft. This is fueled at least in part by a European organization called ACARE (Advisory Council for Aeronautics Research in Europe), which has set a goal of reducing carbon dioxide emissions from aircraft by 50 percent. Airbus is also driven, of course, by the needs — and demands — of its customers. Beral broke these needs into three categories: *flying economically and efficiently* (reduced fuel use, increased plane uptime, reduced maintenance costs); *flying green* (reduced emissions, reduced noise); and flying *simple* (simplified aircraft operation and maintenance procedures).

This futuristic vision also includes advances in airframe technology. Beral identified several opportunities here:

- New fiber and matrix products.
- Fastener-free composite joining materials.
- Increased automation of composites manufacturing.
- Material morphing technology.
- Self-deicing materials.
- Advanced light and hard metallic alloys.
- Smart and multifunctional structures.
- Self-healing and self-repairing structures.
- Alternate fuel systems (fuel cells and all-electric power plants).
- Open-rotor engine configuration.

If all of these technologies were to come to fruition, it is possible that Airbus could realize its commercial aircraft ideal, the attributes of which Beral also included, somewhat tongue-in-cheek: extremely light weight, self-adaptive geometry, non-fossil-regenerated fuel, clean combustion products, inaudible engine and almost 100 percent recyclability/reusability. ■

Bruno Beral is head of structure policy and development at Airbus SAS (Toulouse, France). Previously, he was head of structure research and technology domain, and head of composite structure research, also at Airbus. Prior to Airbus, he worked for almost 20 years at Aerospatiale Aircraft Division (Toulouse, France) on the A320, ATR72 and A340. He is a graduate of Toulouse University.

NEWS

New Airbus consortium established at the National Composite Center

Ohio-based effort will include nanomaterials and carbon-composites research

U.S. Sen. Sherrod Brown (D-Ohio), Airbus Americas Chairman Allan McArtor, and Lisa Novelli, president of the National Composite Center (NCC, Dayton, Ohio) on Jan. 19 announced the establishment of a new aerospace R&D consortium at NCC. The five-year agreement, announced at the NCC site, is aimed at strengthening Ohio's aerospace industry statewide. Airbus is working through the NCC to develop an R&D network of Ohio aerospace suppliers, incubators and universities to develop next-generation products for use in Airbus' new aircraft fleet. The agreement gives Airbus a long-term presence in Ohio manufacturing and research and is the result of an effort between Brown's office and Airbus Americas to foster increased business between the company and Ohio aerospace suppliers. Participating Ohio businesses will receive technical and financial support as they develop and demonstrate new technologies that can produce high-tech parts for Airbus. This supply chain is expected to create and support jobs at Ohio manufacturers and expand R&D opportunities at Ohio colleges and universities.

Source: Sen. Sherrod Brown

"This is about creating jobs by making Ohio Airbus' home in the U.S.," said Brown (pictured in photo). "This new agreement builds on Airbus' commitment to our state, gives Ohio companies new opportunities to develop cutting-edge aerospace materials, and sends Ohio-born next-generation technologies to market worldwide."

"Airbus is proud and excited to be a partner with the NCC and Ohio as we work together to develop the composite technology for the next generation of aircraft," said McArtor, adding that "Airbus' intent is to double its procurement spend in the U.S. over the next few years, and we already have a growing and thriving partnership. I predict even more great things in the future."

In the consortium's first effort, seven Ohio companies and incubators will develop and commercialize new technologies in nanomaterials and carbon fibers for Airbus. The latter has already committed to a $1 million (USD) deal with NCC, the consortium manager, and can issue additional purchase orders over the five-year period of the agreement.

Ohio participants in the consortium include Angstron Materials (Dayton), GrafTech International (Parma), NanoSperse LLC (Kettering), Renegade Materials (Miamisburg), Zyvex Performance Materials Corp. (Columbus), NCC and the University of Dayton Research Institute (UDRI).

PEOPLE BRIEFS

Fiberforge (Glenwood Springs, Colo.) announced on Jan. 10 that veteran **David Cornelius** has been named the company's president and CEO, following his tenure as the company's managing director. Cornelius, who also serves as director of portfolio development for Two Seven Ventures LLC, brings to Fiberforge leadership experience in new ventures, growth strategies and global business management in various fields, including advanced materials, nanotechnology, biotechnology, alternative energy and semiconductor materials. His previous employment included a stint at Dow Corning Corp., where he was executive director of a new-ventures business unit. He holds a BS in chemical engineering from Case Western Reserve University and an MBA from Central Michigan University. **Dr. Jon Fox-Rubin** was named Fiberforge's executive vice-president and will continue to lead strategic projects and oversee business planning, shareholder and employee relations, regulatory affairs, and related corporate business activities. Fox-Rubin cofounded Fiberforge, formerly Hypercar Inc., an automotive technology company that designed a zero-emission SUV and patented the Fiberforge manufacturing process … Seifert and Skinner & Assoc. (Logan, Utah) is pleased to announce the addition of **Leo Ericksen** as senior associate. Ericksen has worked in the composites industry for many years, beginning at Thiokol and its descendent companies, and he was most recently director of marketing and sales for TCR Composites. Ericksen brings a wealth of experience working with filament winding and, especially, prepreg winding systems. He will be responsible for sales of the partnership's trademarked CompositaD filament winding software in North America and other selected regions around the world, as well as other duties.

Aero-engine joint venture opens new plant

CTAL, a joint venture established in 2008 between Rolls-Royce (London, U.K.) and GKN Aerospace (Isle of Wight, U.K.), opened a new facility on Jan. 12 to develop efficient, lightweight jet-engine technology using composites. The CTAL facility will house pilot manufacturing processes that will be used to realize composite fan blade and fan case designs.

Source: CTAL

CTAL's £14.8 million ($23.3 million USD) investment will provide employment for 70 highly skilled engineers on the Isle of Wight and has been supported with £7.4 million ($11.6 million) in funding from the U.K. government. U.K. Business Minister Mark Prisk says, "The U.K. has the world's largest aerospace industry outside the U.S., with a 17 percent share of the global market, which is worth approximately £23 billion [nearly $36.2 billion] per year to our nation's economy. I am pleased to officially open this state-of-the-art facility and to see for myself the work of GKN Aerospace and Rolls-Royce in developing sustainable aviation technologies that will have benefits for marine, health, construction and energy sectors."

Marcus Bryson, CEO and president of GKN Aerospace and GKN Land Systems, adds, "The processes we develop here will be at the heart of the drive to improve the performance of tomorrow's aircraft engines. This facility will help us ensure we and our supply chain sustain the level of technological progress necessary to meet major global aero-engine opportunities in the future." Colin Smith, Rolls-Royce's director of engineering, says his company maintains a long-term commitment to R&D: "This state-of-the-art facility gives us an opportunity to develop world-leading composite technology and manufacturing techniques. These high-technology, lightweight components have the potential to significantly improve the competitiveness of our engines and, hence, reduce the fuel consumption and emissions of future aircraft."

Source: Aurora Flight Sciences

Military OEM passes two milestones in unmanned aircraft contracts

Aurora Flight Sciences (Manassas, Va.) reported on Jan. 9 that it has been awarded a contract by Boeing Defense, Space and Security (St. Louis, Mo.) to design and fabricate structural components for the Boeing *SolarEagle* unmanned aerial vehicle (UAV). The announcement followed a Jan. 3 report that Aurora had delivered the first complete shipset of composite aerospace structures to Northrop Grumman Corp. for the U.S. Navy's *Broad Area Maritime Surveillance* unmanned aircraft system (*BAMS* UAS, see photo) program.

SolarEagle is being developed under the Defense Advanced Research Projects Agency (DARPA) Vulture program. During testing, the *SolarEagle* demonstrator will fly at high altitudes above 60,000 ft/18,288m for 30 days, harvesting solar energy during the day that will be stored in fuel cells and used to provide power through the night. Aircraft that can stay aloft for extended periods can function as pseudo-satellites for intelligence, surveillance, reconnaissance (ISR) and communication applications.

Aurora will design and fabricate the ribs and skins for the 400-ft/122m long wing and the solar collection panels. The work includes components for both a subscale test article and a flight demonstrator. "Aurora will have to push the limits of materials and the imagination to create answers to the demanding requirements of this very large yet gossamer aircraft," says Tom Clancy, Aurora's vice president and chief technology officer. "We are delighted to have been chosen for such an important role. Boeing recognized the value that Aurora brings to the program through our combination of experience in rapid prototyping and our expertise in composite structures." The company's background in human-powered aircraft directly translates to the lightly loaded "gossamer" solar-powered airplanes with low Reynolds numbers. Aurora, in fact, had recently converted one of its early human-powered aircraft into a solar-powered UAV.

Aurora will continue to manufacture the aft fuselage, forward nacelle, midnacelle, aft nacelle and V-tail assemblies of the Navy's MQ-4C *BAMS* UAS aircraft at its composites manufacturing facility in Bridgeport, W.V., and ship the structures to Northrop Grumman's manufacturing facility in Palmdale, Calif., for final assembly.

The MQ-4C *BAMS* UAS is the Navy version of the RQ-4 *Global Hawk* aircraft used by the U.S. Air Force to execute surveillance and reconnaissance tasks. Notably, it has been widely reported that the Air Force's *Global Hawk* program has been cancelled due to military budget cuts.

The Navy's BAMS aircraft, expected to make its first flight in 2012, is a long-endurance aircraft designed to provide ISR information to maritime forces.

General aviation manufacturer to build aircraft factory in Wisconsin

Although the aircraft manufacturer, at *HPC* press time, had yet to issue an official press release, local and aircraft-industry press outlets were alight with news that general aviation (GA) startup Kestrel Aircraft, the newest venture of GA veteran Alan Klapmeier, had selected a factory site in Wisconsin, turning down a previously near-certain location in Maine. *The Portland (Maine) Press Herald* reported on Jan. 17 that Kestrel, which plans to build a composites-intensive single-engine turboprop plane, will build its manufacturing plant in Superior, Wis., after Maine officials failed to secure adequate financing for the company. Kestrel had announced in 2010 that it would move to Brunswick Landing, Maine, and employ as many as 600 workers to build the new type of six- to eight-passenger turboprop (see photo). According to the report, the state of Wisconsin developed a more attractive plan to provide federal tax credits for the $100 million (USD) manufacturing facility.

Klapmeier, Kestrel's CEO and chairman, commented that some Maine officials failed to follow through on a financing plan that he thought was in place in 2010. *The Portland Press Herald* quoted Klapmeier in a Jan. 13 report: "We did not say, 'Tell us your best offer and we'll go and play it against someone else.'" Klapmeier also was said to insist that the company wasn't interested in trying to "take a bunch of money from people and then go and take a bunch of money from someone else."

According to the Jan. 17 report, Maine Gov. Paul LePage announced on Jan. 13 a total of $7.75 million in possible loan guarantees to bridge a financing gap. In contrast, Wisconsin proposed financing that involves the federal New Markets Tax Credit Program. The Wisconsin Housing and Economic Development Authority will provide $30 million in tax credit allocations immediately, a second allocation of $30 million by the end of this year and a commitment for a third allocation of $30 million in 2013 if the authority has the funds available, Klapmeier said. By contrast, the company received a $20 million tax credit allocation in Maine, and the status of future allocations was unclear.

Source: HPC/Photo: Sara Black

The report says Kestrel plans to keep 25 engineering support and aircraft modification jobs in Brunswick and then add functions. Another published report, in the *Minneapolis/St. Paul Business Journal*, dated Jan. 16, said Kestrel was able to procure land in Superior's former fairgrounds, for $500,000. According to a second story, the Wisconsin Economic Development Corp. will create an "enterprise zone" in Superior to enable the tax credits.

BIZ BRIEF

On the strength of its record annual revenue growth in 2011, **Verisurf Software Inc.** (Anaheim, Calif.) is expanding into a new corporate headquarters just down the street from its current location. The new site also will house its metrology training center. The company's consistent growth, it says, is due to increasing implementation of Verisurf 3-D measurement solutions in manufacturing companies, ranging from small machine shops to large aerospace companies. Ernie Husted, president and CEO, says, "I am very encouraged by our record number of new customers, which points to increasing demand for our advanced 3-D measurement solutions."

The company's existing Anaheim location and the new facility accommodates the software development team (products include computer-aided inspection and reverse-engineering solutions), technical support, the application engineering, sales and marketing functions, and the distribution warehouse. A major facility element, the metrology training center, features extensive laboratory space, tractor-trailer access and a 5-ton overhead lift for moving large-scale measurement artifacts.

BIZ BRIEFS

Quatro Composites (Orange City, Iowa), a wholly owned business of Tec Industries LLC that offers design, analysis, prototyping and production of advanced composite products, announced on Jan. 10 that it has been awarded a milestone contract to certify and produce Boeing 787 *Dreamliner* stowage bin fittings for the 787-9 model. "We are honored to be a part of this exciting new generation of aircraft," says Quatro Composites' president Steve Roesner. Quatro Composites and the Boeing Fabrication Interiors Responsibility Center will work together to certify the composite fittings. Entry into service will coincide with the 787-9 configuration.

Seifert and Skinner & Assoc. (Logan, Utah, and Hasselt, Belgium) has expanded its composites laboratory and opened a new testing facility and office in Hasselt. Managing associate Axel Seifert says the 400m^2 (4,300 ft^2) facility will give the company plenty of room for the equipment necessary to perform prototype fabrication of, and nearly all of the testing required to design and certify, composite pressure vessels used to store and transport liquefied petroleum gas (LPG) and compressed natural gas (CNG).

BIZ BRIEFS

MAG IAS (Erlanger, Ky.) has reported the first purchase of its new GEMINI Composite Processing System, which is capable of switching from automated fiber placement (AFP) to automated tape laying (ATL) in a matter of minutes. The system will be installed at Alliant Techsystems' (ATK, Eden Prairie, Minn.) Iuka, Miss., facility and will be the eighth MAG fiber placement system installed at ATK plants. The gantry system incorporates MAG's VIPER AFP head and either MAG's CHARGER or Forest Liné's (Granby, France) ATLAS ATL heads. (For more details about the system, see "New Products," p. 57-59).

TenCate Advanced Composites North America (Morgan Hill, Calif.) has relocated its former Benicia, Calif. prepreg operations to a 65,000-ft^2 (6,040m^2) facility in nearby Fairfield, Calif., avoiding the loss of the company's highly skilled work force. It consolidates three separate Benicia sites into one for greater efficiency and flow in manufacturing. Paul Draghi, VP of manufacturing, says the Fairfield facility, extensively upgraded and AS9100:2009 Rev C-approved, complements TenCate's existing Morgan Hill, Calif. facility, providing customers with two supply sites for redundancy and additional capacity.

Source: Spirit AeroSystems

First A350 XWB composite center-fuselage section is delivered

Spirit AeroSystems Inc. (Wichita, Kan.) reported on Jan. 9 that it has successfully delivered its first composite center-fuselage section (see photo) for the Airbus A350 XWB program. The upper and forward lower shell (Section 15) composite fuselage panels were joined in Spirit's Saint-Nazaire, France, facility before the barrel section was delivered to Airbus.

Spirit won the Section 15 contract with Airbus in May 2008. The first center-fuselage panels were shipped from Spirit's North Carolina facility to its Saint-Nazaire facility in October 2011. Spirit also designs and builds the plane's composite front wing spar and fixed leading edge, which have already been delivered to Airbus in the U.K.

Mandrel maker celebrates 65th year of service

Lynco Grinding Co. (Bell Gardens, Calif.) is celebrating a rare milestone in March: 65 years in business serving the composites industry. The mandrel specialist opened its doors in 1947, launched by Harold Hogarth, who saw and seized an opportunity in the fishing-rod industry. Wayne Hogarth, Harold's son and current president of the company, says that after World War II, American consumers returned to leisure pursuits like fishing. Until then, rods had been made from split bamboo or steel. Supply of the former proved unreliable, and the latter proved dangerous, thanks to their ability to attract lightning strikes. Fiberglass, therefore, seemed like an ideal alternative, but the challenge was development of small-diameter, tapered mandrels for layup of the rods. "Nobody could do it," Wayne says. "But my dad did it. It's still very difficult today."

The company still makes the small-diameter, tapered mandrels that got it started, but it also has branched out into other markets, including aerospace and fiber and tape placement. Wayne says the company's smallest diameter mandrel today is 0.010 inch/0.254 mm, and its largest is 5 ft/1.5m. Material types used include alloy carbon steel, aluminum, bronze, brass, copper, composites and glass. "If it needs a tool, we'll build it," he says.

Although the company has developed processing expertise, Wayne says the focus remains on the manufacture of quality mandrels for composites applications. "We've been asked to get into production, but we feel that would be an injustice to our customers."

Today the company employs 12 people who have worked there from 8 to 30 years. Lynco founder Harold is retired, and he and his wife, Mary, are about to celebrate a milestone of their own: 70 years of marriage. Wayne says a formal celebration of the company's birthday isn't planned, but it's still a big deal: "I'm proud of the fact that we have been continuously operating in the composites industry for such a long time, doing one thing and doing it well."

New HVARTM carbon-composite process tested

In January, Advaero Technologies Inc. (Greensboro, N.C.) reported that it had successfully completed initial trials of a new carbon composite part made from a unique fabric technology that was processed with Advaero's new (pat. pend.) heated vacuum-assisted resin transfer molding (HVARTM) process. The company is a member of a global consortium, led by Dr. Stephen Tsai, professor research emeritus at Stanford University, that includes Stanford's Department of Aeronautics & Astronautics (Palo Alto, Calif.) and Chomarat Textile Industries (Le Cheylard, France). The company is a commercial spinoff from North Carolina A&T State University's College of Engineering. Advaero is focused on advanced composite structures that feature thin-ply, bi-angle, noncrimp fiber technology, as reported previously in *High-Performance Composites* (see *HPC* July 2011, p. 9, or visit http://short.compositesworld.com/NszadkNW).

Advaero's HVARTM process was found to be effective in tests when coupled with Chomarat's newly developed 150-g/m^2 bi-angle, noncrimp carbon fiber fabric, resulting in a composite structure with tensile strength that is three times greater than composites made by conventional methods with standard carbon fiber fabrics. Moreover, the process does so without an autoclave cure. The resulting composite's strength-to-weight and projected lower processing costs could make it attractive to manufacturers of commercial aircraft components.

In the Jan. 12 announcement, Advaero CEO Greg Bowers contended that "Advaero's HVARTM infusion process, combined with Chomarat's new carbon fiber fabric, creates a technology platform that could launch stronger, lighter components and structures at competitive prices."

"We are excited and pleased to see the Advaero-infused composite product yielding such impressive physical results," added HVARTM co-inventor and scientific advisor to Advaero, Dr. Ajit Kelkar.


Photo: Jeff Sloan

2012 SAMPE EUROPE PREVIEW

The SEICO 12 theme, "Strong Features to Support Lift-Off," calls attention, in part, to advanced composites aboard the Airbus A400M military transport aircraft.

The European branch of the Society for the Advancement of Material and Process Engineering (SAMPE) will host its 33rd SAMPE Europe Conference and Forum (SEICO 12) at Hotel Mercure, Paris Porte de Versailles Expo, Vanves. The event will begin a day earlier than the nearby JEC Europe 2012 conference and exhibition (see article on opposite page), on March 26. As it has during the recent recession, the previously three-day conference will be packed into two days, ending on the afternoon of March 27. The abbreviated schedule will permit SEICO attendees up to two full days at the JEC Europe 2012 conference venue without missing any SAMPE conference sessions. As always, SAMPE Europe attendees can use their SEICO 12 badges to gain free access to the JEC show. A free bus shuttle service will operate on Tuesday, March 27, between Hotel Mercure and the main entrance of the JEC Europe exhibit hall at the Paris Expo, from 8:00 a.m. to 6:00 p.m.

The highlight of the event is the keynote speaker and plenary session devoted to the Airbus A400M military transport's composites programs. José Manuel Luna Diaz, senior expert and head of production and development engineering for Airbus Military (El Puerto de Santa Maria, Cadiz, Spain) will speak on the subject of "Cultural Revolution from Pure Metal to Today's Composites and Hybrids." At the plenary session that immediately follows, Dr. Leslie Cohen (HITCO Carbon Composites, Gardena, Calif.) will moderate four presentations that will cover the A400M's design/certification, manufacturing, assembly and full-scale testing innovations. To preview the balance of the two-day technical conference, see "SAMPE Europe at a Glance," at right.

WHAT:	**33rd SAMPE Europe Conference and Forum (SEICO 12)**
WHEN:	**March 26-27**
WHERE:	**Hotel Mercure, Porte de Versailles, Paris, France**

SAMPE Europe's annual Welcome Reception will be held the evening before the conference, on Sunday, March 25, at Hotel Mercure in the atrium outside the hotel conference rooms. Conference attendees who arrive early can participate in the reception, where finger food and drinks will be served from 6:30 to 8:00 p.m. Refreshments and meals will be catered for the entire event, including a Welcome Coffee on both mornings, a buffet luncheon at the hotel restaurant (a voucher will be provided by SAMPE) and afternoon breaks. Each attendee of SEICO 12 will receive a complimentary copy the *Proceedings of SEICO 12*, in English on CD. Additional copies may be purchased during the conference at a special price of €70 each.

For more information about SEICO 12, *contact* SAMPE Europe| *E-mail: sebo@sampe-europe.org; Web site: www.sampe-europe.org.* ■

SAMPE Europe at a Glance

Sunday, March 25

Registration	8:00 a.m. to 4:30 p.m.

Monday, March 26

Registration	8:00 a.m. to 4:30 p.m.
Keynote Presentation	9:00 a.m. to 10 a.m. Jose Manuel Luna Diaz, Airbus Military (Cadiz, Spain)
Coffee Break	10:00 a.m. to 10:30 a.m.
Plenary Session	10:30 a.m. to 12:00 noon Aerospace: A400M Military Transport
Lunch	12:15 p.m. to 1:15 p.m.
Session 2	1:30 p.m. to 3:30 p.m. Nanocomposites Textile Reinforcements
Session 3	4:00 p.m. to 6:00 p.m. Composites Manufacturing Analysis of Composites
SEICO Dinner	7:30 p.m. to 10:30 p.m.

Tuesday, March 27

Registration	8:00 a.m. to 4:30 p.m.
Session 4	8:30 a.m. to 9:50 a.m. Repair of Composites The iREMO Project
Coffee Break	9:50 a.m. to 10:20 a.m.
Session 5	10:20 a.m. to 12:15 p.m. Composite Design Composite Materials
Lunch Break	12:15 p.m. to 1:15 p.m.
Session 6	1:30 p.m. to 3:30 p.m. The IMAC-PRO Project Thermoplastic Composites
Coffee Break	3:30 p.m. to 4:00 p.m.
Session 7	4:00 p.m. to 6:00 p.m. Liquid Composite Molding Novel Composite Applications Student Conference
Conference Closure	6:00 p.m. to 6:10 p.m.

2012 JEC EUROPE PREVIEW


Photo: Jeff Sloan

JEC's annual Paris exhibition adopts a new name in keeping with its status as a globetrotting trade show company.

Now an annual tradition and, in terms of numbers, the number one gathering for composites professionals worldwide, the JEC Composites Show will fill the Paris Expo, as it has since 2002, from March 27-29. The sights, sounds and opportunities will be familiar, but one thing will change. The show will bear a new name, JEC Europe, to distinguish it from JEC's show in Asia and the newly announced JEC Americas show, which is coming to the U.S. in late 2012 (Boston, Mass., Nov. 7-9). Organizers predict that the Paris event will, as it has in recent years, attract more than 20,000 composites industry professionals and at least 1,000 exhibitors.

JEC is expanding its presence worldwide in anticipation of what JEC market research predicts will be significant industry growth. "The worth of the global composite market went from €38 billion [$39.7 million] in 2000 to €72 billion $94.2 million] in 2011," says JEC Group president and CEO Frédérique Mutel. "We are expecting growth worldwide. At an average 6 percent per year increase, our market will be worth €91 billion by 2015." Mutel credits "cooperative associations" and "transnational value chains" for much of the success. Not surprisingly, then, an emphasis at the JEC show in 2012 will be networking opportunities.

Networking is only one facet of what JEC says is a threefold show theme: *innovation networks*, *automation* and *recyclability*. The second facet, automation, will be emphasized in recognition of advances realized most significantly in North America and Europe. JEC expects its exhibitor base to be heavy with purveyors of automated means to handle, form, assemble and finish composites. The third facet, recyclability, will honor an area of innovation in which Europe has taken the global lead with ambitious end-of-life legislation among EU participants, creating a hot spot for developers and users of readily reclaimed thermoplastics and plant-based fiber reinforcements. Additionally, show organizers have selected the U.K. as the exhibition's "country of honor" for its reputation as fertile ground for composites innovators.

Off the show floor, JEC will again host the I.C.S. (International Composites Summit), a preview of trends in composites applications. In its second year, the event will provide a forum for 100 key players in the international composites market. Its stated goal? To foster dialog among academicians, industrialists and product end-users. Forums and meetings will center on case studies, and lectures will be given by experts in composites R&D, design and production.

In parallel, the C.S.N. (Composites Scientific Network) will provide a forum for cooperation between academicians and industrialists. Its goals are to establish guiding principles, expedite access to scientific development and facilitate the exchange of knowledge.

WHAT:	**JEC Europe 2012**
WHEN:	**March 27-29**
WHERE:	**Paris Expo, Porte de Versailles, Paris, France**

Reflecting industry expansion

Now known as JEC Europe, this annual Paris conclave is sporting not only a new name but also is celebrating expected industry growth.

Returning after its debut last year is the JEC Job Center. Exhibitors will display current job postings, and visitors can use the center as a cost-free means to distribute résumés.

Last but certainly not least is the annual JEC Innovation Awards program, now known as Innovations Awards Europe (a separate awards program will be held at the JEC Americas show in Boston). According to JEC, more than 1,600 companies have submitted composite products for review by JEC's panel of judges in the awards program's 14-year existence. Since its inception in 1998, more than 150 composites manufacturers, together with almost 360 partners, have taken home honors.

For more information about JEC Europe 2012, *contact the* JEC Group; *Tel*.: + 33 1 58 36 15 01; *Fax*: + 33 1 58 36 15 15; *E-mail: visitors@jec-composites.com*; *Web site: www.jeccomposites.com*.

Plan your visit! See the JEC Europe 2012 *exhibitor list with booth locations on the following pages or (with a show floor map) at the CompositesWorld Web site: http://short.compositesworld.com/DuYp7tDk*.

2012 JEC EUROPE EXHIBITOR LIST

Company	Aisle & Booth#
01dB Metravib	P82
2 Komponenten Maschinenbau GmbH	L45
3B - The Fibreglass Comapny	D4
3D-Core	M24
3M	L15
5M	R73
A&P Technology	**N58**
Abahsain Fiberglass M.E., W.L.L.	T29
Abitad GRP (Nanjing) Co. Ltd.	W40
Abrasifs Services Skilled France	Y32
Accudyne Systems Inc.	F43
Acmos Chemie KG	S79
Additek SaS	TBD
Aditya Birla Chemicals (Europe) GmbH	TBD
Advanced Composites Group Ltd.	T50
Advanced International Multitech Co. Ltd.	L52
Advanced Textiles & Materials	U26
Aero Consultants AG	M63
Aeroform France	G74
Aeron Composite Pvt. Ltd.	D71
Aerospace Manufacturing	TBD
Aerospace Research Institute of Materials & Processes	TBD
Aerovac Systemes France	T50
AFC-STAB	V20
AFPT GmbH	R79
Agteks Ltd.	V19
AGY Holding Corp. (Advanced Glassfiber Yarns)	M25
Ahlstrom Glassfibre Oy	G9
AIC - Europe Technologies	V20
Aiki Riotech Corporation	TBD
AIP	T8
Airborne International	P45
Airex AG	N32
Airtech Europe Sarl	**M64**
AKPA Organic Peroxides & Initiators	E64
AKSA Karbon Sanayi AS	K45
Allio SaS	V20
Alpha Technologies	TBD
Altona	L84
Alzchem Trostberg GmbH	D46
American Autoclave	S14
Amorim Cork Composites	X72
AMP Composites Co. Ltd.	TBD

Company	Aisle & Booth#
Anaglyph Ltd.	X64
Anguil Environmental Systems Inc.	G43
ANSYS France SaS	TBD
AOC LLC	F57
Apatech	D75
Arex de Picardie/CCI International Picardie	TBD
Argosy International Inc.	U38
ARI Picardie	TBD
Armacell Benelux SA	S51
Arsan Kaucuk Plastik Makine Sanayi Ve Tic AS	U20
Asahi Diamond Industrial Europe SaS	V78
ASC Process Systems Inc.	**S57**
Assembly Guidance Systems Inc.	W72
Atom Beraud	B25
August Herzog Maschinenfabrik GmbH & Co. KG	L82
Aurock	TBD
Autoclave & Industrial Controls (AIC)	TBD
Autoclaves Group	TBD
Automated Dynamics	**F43**
Avangard JSC	T9
AWEX	G12
Axel Plastics Inc.	P52
Axiome	V20
Axson Technologies	P79
Axxor BV	J50
Azelis	D45
B. Laufenberg GmbH	L78
Baden-Württemberg International GmbH	TBD
Bally Ribbon Mills	D44
Bamboo Fibers Technology	L80
Basaltex - Flocart NV	K70
BASF SE	G17
Baycomp Co.	Q52
Bayer MaterialScience AG	P14
Bayern Innovativ GmbH	F29/ F31
Beijing Partnerworld Int'l Exhibition Co. Ltd.	TBD
Belotti SpA	H66
Besne Mecanique de Precision	V20
Biorenforts	TBD
BITEAM AB	V77
Bluestar Fibres Co. Ltd.	H3
Bondi (Shandong) Environmental Material Cc. Ltd.	TBD
Bond-Laminates GmbH	R38
Boytek Recine Boya ve Kimya San Tic	M51

Company	Aisle & Booth#
Breton SpA	N79
Brötje-Automation GmbH	TBD
Bureau Veritas Laboratoires	R75
BYK-Chemie GmbH	G19
C.A. Litzler Co. Inc.	**G43**
Cabot	C66
CADFEM GmbH	TBD
Cam Elyaf Sanayii AS	M32
Cambium	TBD
Cannon France	H70
Cannon SpA	H70
Carbon Composites EV	TBD
Carbone Forgé	N19
Carbopress Srl	R63
Carus Srl	C40
Cavitec AG	S60
CCP Composites	TBD
CCPIT Building Materials Sub-Council	TBD
Cel Components Srl	D55
CELC - Masters of Linen	TBD
CEMCAT	V20
Censol Ltd.	V72
Centreco	V78
Century Design Inc.	V43
Cetex Institut für Textil und Verarbeitungsmaschinen Gemeinnützige GmbH	T66
CETIM	V20
CFK-Valley Stade EV	TBD
CGTech	**R66**
Changzhou Hongfa Zongheng Advanced Material Technology	Q32
Changzhou Pro-Tech Industry Co. Ltd.	U44
Changzhou Tiansheng New Materials Co. Ltd.	TBD
Chem-Trend (Deutschland) GmbH	TBD
China Composites Group Corporation Ltd.	P58
China Jiangsu International Economic Technical Cooperative	D32
China National Building Materials Corp.	T44
Chomarat Textiles Industries	Q25
Chongqing Peak Pipeline Co. Ltd.	TBD
Cimteclab SpA	TBD
Cipec Specialites	K37
Clariant International AG	R4
Click Bond Inc.	N72
Clix Industries	TBD
Clubtex	TBD
CMG	T75
C-M-P	Q58

Company	Aisle & Booth#
CMS SpA	Q18
CNBM International Corp.	N23
CNBM Technology	U43
Coexpair	T81
Cogit Composites	N65
Comi Spa	M37
Compose	M57
Composite Integration Ltd.	G74
CompositesWorld	**A31**
Conseil Et Technique	TBD
Conseil General de la Charente Maritime	C45
Conseil Regional de Picardie	TBD
Coral SpA	TBD
Corex-Honeycomb	F63
Corima Technologies	TBD
Coriolis Composites	TBD
CPC Group	R63
CPIC/Fiberglass	TBD
CPS Technologies	Z44
Creaform France SaS	V71
Critt Polymères Picardie	TBD
CRST SaS	TBD
CTC GmbH	TBD
Cytec Engineered Materials	G31
D. K. Holdings Ltd.	R37
Daher Aerospace	V76
Dalian Xingke Carbon Fiber Co. Ltd.	TBD
Dalian Yuxing Water Treatment Equipment Co. Ltd.	TBD
Dallet	TBD
Dassault Systèmes	R65
Daxen	TBD
DBW Fiber Neuhaus GmbH	Z43
Dedienne Multiplasturgy Group	W76
Delcam Plc	L25
Delphia Yachts Kot Sp. J.	X26
Delta-Preg SpA Uninominale	M26
Despatch Industries LP	H46
Devold AMT AS	TBD
DFC/DCP	TBD
DIAB International AB	K26
Diamix	M30
Diatex SaS	G74
Dieffenbacher GmbH Maschinen und Anlagenbau	P32
Dil	V20
Dipex sro	S9
Diversified Machine Systems (DMS)	TBD
DJP Espace Composites	Q75

Company	Aisle & Booth#
DLR German Aerospace Center	H56
Dow Chemical Co., The	B19
DPS Composites	M37
DS Fibres	R77
DSM Composite Resins AG	D9
Dunstone Co. Inc.	S64
Dupont International Operations Sarl	S63
Duqueine	P46
DA Aluminium Composites	Y63
Dynabrade Europe Sarl	R29
EADS Deutschland GmbH	TBD
Eastern Industrial Company - EICO	T12
Eastman Machine Co.	U8
EHA Composite Machinery GmbH	J38
Eisenmann Anlagenbau GmbH & Co. KG	Y72
Elantas Camattini SpA	J11
Electroimpact	TBD
ELG Carbon Fibre	M71
Eligio Re Fraschini SpA	W90
ELKOM Heizplattentechnik GmbH	W74
EMS-Chemie AG	X60
EPC Engineering Consulting GmbH	Y72
Epotech Composite Corp.	T13
Epsilon Composite	P64
Equip Aero Technique	TBD
ERPRO	Q69
ES Manufacturing Inc.	G43
ESI Group	Q80
ETIM	V20
EuCIA	TBD
Eurocarbon BV	R43
Evonik Industries AG	**G66**
Evs	D
Faserinstitut Bremen EV	TBD
Feicheng Sanying Fiberglass Co. Ltd.	TBD
Fiberforge	**K66**
Fibertex AS	TBD
Fibertex Nonwovens A/S	N44
Fibres Recherche Developpement	TBD
Fibretech Composites GmbH	TBD
Fill GmbH	U39
Fimalin	X75
Finish Kare Products Inc.	G43
Flow Europe GmbH	T19
Flugzeug-Union Süd GmbH	TBD
Foamtech Co. Ltd.	P43

Company	Aisle & Booth#
Formax UK Ltd.	N52
Formes et Outillages	N64
Formosa Plastics Corp.	M45
Fraunhofer IZFP-D	T66
Fraunhofer Pyco	D66
Fraunhofer-Gesellschaft	TBD
Fraunhofer-Institut für Fertigunstechnik und Angewandte Materialforschung (IFAM)	TBD
Frenzelit Werke GmbH	TBD
Frimo Group GmbH	T91
FRP Services Europe Sarl	D19
Fujairah Fiberglass Factory	TBD
Fujian Haiyuan Automatic Equipments Co. Ltd.	D32
Futurecarbon GmbH	E45
G. Angeloni Srl	W64
Galstaff Multiresine Spa	C32
Gavazzi Tessuti Tecnici Spa Socio Unico	D31
Gazechim Composites	K43
Gbf Basalt Fiber Co. Ltd.	D50
Gebe2 Productique	P80
Geiss AG	**P39**
Georg Sahm GmbH & Co. KG	D29
Gepo France Sarl	TBD
Gerber Technology	M46
Germa Composite GmbH	TBD
Gigantex Composite Technologies Co. Ltd.	R9
Gma-Werkstoffprüfung GmbH	TBD
Gordon Composites	Q39
GPIC - Division Composites	TBD
Graco BVBA	B39
Grafil Inc.	J31
Granta Design	D65
GRPMS	T50
Gunnar	S81
Gurit	K44
Hampson Aerospace Services	B65
Harbin Yidao Science & Technology Co. Ltd.	TBD
Harper International	**T51**
Hebei Shengwei Jiye FRP Products Co. Ltd.	D32
Helm AG	J25 & K19
Henkel	R45
Hennecke GmbH	K31
Heraeus Noblelight France	R55
Hexagon Metrology	U80
Hexcel	G57

Company	Aisle & Booth#
Hightex Verstarkungsstrukturen GmbH	T66
Hilger U. Kern GmbH	E57
Hindoostan Technical Fabrics Ltd.	TBD
Höfer Presstechnik GmbH	P78
Holding Company Composite	F19
Hongming Composites Co. Ltd.	TBD
Hos-Technik Vertriebs - und Produktions GmbH	G24
HP Composites Srl	Y26
HPF - The Mineral Engineers	F25
Hufschmied Zerspanungssysteme GmbH	TBD
Huguet Ingenierie	V20
Hungarian Investment and Trade Agency (HITA)	TBD
Huntsman Advanced Materials (Switzerland) GmbH	G65
Hutchinson SNC	G56
Hymmen Industrieanlagen GmbH	X29
I Ma Tec Srl	D69
Ilium Wll	T29
IMA Materialforschung und Anwendungstechnik GmbH	T66
Impetus AFEA	TBD
Impianti Oms SpA	M37
Inasco	P73
Inchem Corp.	F43
Ingenieria de Compuestos SL	TBD
Ingersoll Machine Tools Inc.	**F51**
Innegra Technologies LLC	E69
Innovoc Solutions	Q39
Institut fuer Verbundwerkstoffe GmbH	C37
Instron	**D51**
Intermas Nets SA	S8
Isojet Equipements	F56
Isomatex SA	N74
Isowood GmbH	TBD
IST - Industrial Summit Technology	N56
Italmatic Presse Stampi Srl	T7
Itasa	F23
Itochu Corp.	R13
I-Trans	TBD
ITW Windgroup	K65
Izumi International Inc.	**U40**
Jacret SA	P40
Jallais Industrie	V20
JB Martin	S6
JD Lincoln	T50
Jedo Technologies	TBD

Company	Aisle & Booth#
Jiangsu Changhai Composite Materials Holding Co. Ltd.	Q44
Jiangsu Hengshen Fiber Materials Co. Ltd.	T82
Jiaxing Longshine Carbon Fiber Products Co. Ltd.	TBD
Jiaxing Sunny Frp Industries Co. Ltd.	L66
Jiaxing Youwei Composite Material Co. Ltd.	U30
JOBS SpA	Z46
Johns Manville Slovakia	G46
Jost Chemicals GmbH	Q10
JPS Informatique	TBD
JX Nippon Anci	V90
Kaman Composites - Vermont	G43
Kanto Yakin Kogyo Co. Ltd.	P55
Karl Mayer Malimo Textilmaschinenfabrik GmbH	T66
Karlsruher Institut für Technologie (Kit)	W73
Kemrock Industries and Exports Ltd.	G26
Keyser et Mackay (France) et Cie	L71
Khimvolokno	C74
Kistler France	F1
KNF Flexpak Corp.	F43
Knierim Tooling GmbH	N71
Koller SaS	Q69
Kolon Industries Inc.	D37
KraussMaffei Technologies GmbH	P38
Kretzer Scheren GmbH	P51
Kroenert GmbH & Co. KG	Q71
Ksl Keilmann Sondermaschinenbau GmbH	P74
Kuka France	P75
Kush Synthetics Pvt. Ltd.	TBD
Lach Diamant Jakob Lach GmbH & Co. KG	TBD
Lamiflex	W44
Landeshauptstadt Dresden AMT für Wirtschaftsförderung	T66
Langzauner GmbH	U76
Lantor BV	T45
Lap GmbH Laser Applications	H74
Laser Projection Technologies Inc.	T79
Laser Zentrum Hannover EV	TBD
Lavesan Srl	M39
Le Creneau Industriel	P49
Lectra	TBD
Lehmann & Voss & Co KG	M65

Company	Aisle & Booth#
Leibniz-Institut fur Polymerforschung Dresden EV (German Pavilion)	T66
Lianyungang Weide Composite Materials Facilities Co. Ltd.	Q40
Libeco Lagae	TBD
Limoges Usinage Mecanique	T3
Lineo	TBD
Lintex International Co. Ltd.	S12
LJF - Le Joint Francais	G56

Company	Aisle & Booth#
Lonza	Q74
Lopotec Composites GmbH	TBD
Louisiana Economic Development	F43
Luna Innovations	G43
MTorres Diseños Industriales SA	**P65**
Mag Europe GmbH	TBD
Magestic Systems	TBD
Magnabosco Srl	K25
Magnum Venus Plastech	T32

Company	Aisle & Booth#
Mahr Metering Systems GmbH	M66
Mankiewicz Gebr. & Co	T14
Mapal	G55
Marbocote Ltd.	Q20
Masnada Diamant Industrie	TBD
Matrasur Composites	T30
McClean Anderson	**Y59**
McLube Asia Pvt. Ltd.	V29
MDC Mould & Plastic Co. Ltd.	L51

Company	Aisle & Booth#
Mecafi	R63
Mecanic Vallee	TBD
Mescan	TBD
Metton America Inc.	TBD
METYX Composites	Q43
MF Tech	P75
Micado Smart Engineering	TBD
Microtex Cotton Club SpA	TBD
Midi-Pyrenees Expansion	TBD
Mikrosam AD	M75

Company	Aisle & Booth#
Mil's	G74
Mir Ar Ge Inc.	B33
Mitsubishi Rayon Co. Ltd.	J31
Momentive Specialty Chemicals GmbH	G45
Mozart AG	V37
Mubea Carbo Tech GmbH	L35
Multiax International CNC Srl	S3
Multiplast	TBD

Company	Aisle & Booth#
Nabertherm GmbH	Z62
Nagase & Co. Ltd.	TBD
Nanjing Huapeng Fiberglass Equipment Manufacturing Co. Ltd.	TBD
Nanjing Loyalty Composite Equipment Manufacture Co.	T63
Nantong Composite Material Co. Ltd.	H23
Nantong Shiru Reinforced Plastic Products Co. Ltd.	TBD

Company	Aisle & Booth#
Nantong Strongworld FRP Products Ltd.	Q14
NASA/Jacobs Technology	F43
National Aerospace Laboratory NLR	P56
Netzsch GmbH	R80
Neuhäuser Präzisionswerkzeuge GmbH	T59
New Fire Co. Ltd.	TBD
Nextrusion GmbH	Z60
Nida Maine / Maine Plastiques	V20

Company	Aisle & Booth#
Nidaplast Composites	Q24
Nief Plastic	T8
Nippon Electric Glass Co. Ltd.	L49
Nippon Graphite Fiber Corp.	N40
Norafin Industries GmbH	F69
Nord Composites	G44
North Thin Ply Technology	J3
Novation Tech SpA	D76
NRW International GmbH	U58

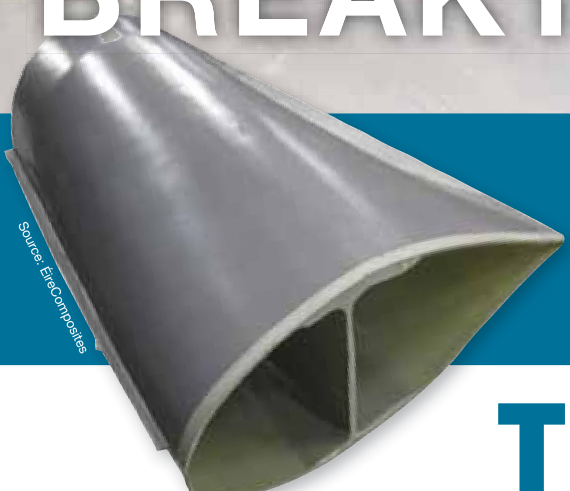
Company	Aisle & Booth#
OCV Reinforcements	R20
Oerlikon Balzers Coating Luxembourg Sarl	T76
Oerlikon Balzers France	T76
Oerlikon Barmag Zweigniederlassung der Oerlikon Textile GmbH & Co. Kg	T76
Oerlikon Leybold Vacuum	T76
Olmar SA	TBD
Olnica	Z64
Olympus France	TBD
Oxeon	P25
Parabeam BV	G29
Park Electrochemical Corp.	**U18**
P-D Glasseiden GmbH Oschatz	P19
Pergan GmbH	Q51
Phoenix Equipment Co.	F43
Piercan SA	P72
Pinette Emidecau Industries	L58
Plascore GmbH & Co. KG	**L70**
Plasticell	U36
Plasticon Europe	D39
Plastipolis	TBD
PMC - Performance Materials Corp.	Q52
Pole de Competitivite EMC2	V20
Pole de Plasturgie de l'Est	TBD
Pole LAR	TBD
Poliya	G47
Polotsk Steklovolokno JSC	U74
Polyecim Composites	V20
Polyfont SaS	TBD
Polyprocess SaS	V39
Polystrand	Q39
Polytec Composites Germany GmbH & Co	D72
Polyworx BV	Y46
Porcher Industries	G20
Portelli Productions	TBD
Potters Europe	T78
PPG Coatings SA	Q64
PPG Industries Fiber Glass Europe	TBD
Procotex	N84
Productos Concentrol SA	C72
Propex Fabrics GmbH	W12
Protechnic	V73
PSC Inc.	G43
Pultrex Ltd.	T80
Pyromeral Systems	M73
QDesign Srl	TBD
Qingdao Fundchem Co. Ltd.	K49
Q-Lab Europe Ltd.	U14
Qpoint Composite GmbH	T66

Company	Aisle & Booth#
Quantum Composites Inc.	R39
Quickstep Technologies	E
Quimiasiatico de Composites SL	TBD
Recaero Composites	TBD
Reichenbacher Hamuel GmbH	TBD
Reliant Machinery Ltd.	TBD
Renolit Gor SpA	E24
Repmo Machines-Outils	S75
Rescoll	TBD
Resoltech Sarl	P20
Respecta Maschinenbau GmbH	K74
Rexco Mold Care Products	D33
Rhodia Engineering Plastics	B66
Richmond Aerovac	T50
Richmond Aircraft Products Inc.	T50
Ritter GmbH	F65
Robotmaster – 3IDM	P80
Robuso Stahlwarenfabrik Buntenbach & Sohn GmbH	P66
Robust Habicht & Heuser GmbH & Co KG	TBD
RocTool	M31
Rossow Industries	Q73
Rubbercraft	Z56
Saati Spa	V36
SABIC Innovative Plastics	TBD
Sächsisches Textilforschungsinstitut EV	T66
Saertex GmbH & Co KG	M19
Safilin	TBD
Safran - Structil	L19
Saimap - Viennot	V78
Sami Tongun Camelyafli Polyester Urunleri AS	TBD
Sandvik Coromant AB	W11
SAT	TBD
SCEI	L63
Schappe Techniques	M20
Schmalz, J. GmbH	M70
Schuler SMG GmbH & Co. KG	T97
Scigrip	D43
Seco Tools	TBD
Seifert And Skinner & Associates, Bvba	D25
Selcom Srl Multiaxial Technology	T40
Semi Dice International BV	Z44
Sepma Srl	TBD
SGL Technologies GmbH	H31
SGS Carbide Tool (UK) Ltd.	TBD
Shanghai Precision Dosing & Weighing System Co. Ltd.	T77

Company	Aisle & Booth#
Shanghai Zen3 International Exhibitions Co. Ltd.	D32 & D82
Shikibo Ltd.	Y38
Sichuan Weibo Co. Ltd.	K50
Sichuan Xinwanxing Carbon Fiber Composites Co. Ltd.	D32
Sicomin	W66
Siemens	L65
Siempelkamp Maschinen- und Anlagenbau GmbH & Co. KG	S73
Sigmatex Ltd.	R32
Sika Deutschland GmbH, Tooling & Composites	P29
Siltex Srl	B24
Sir Industriale SpA	Q49
SL Laser France Sarl	M69
SMTC	TBD
Societe Publique Regionale des Pays de la Loire	V20
Soficar SA/Toray Industries Inc.	J13
Soloplast Vosschemie	M44
Sönmez Textiles Advanced (STA Composites)	TBD
Sora Composites	M76
Soteco SpA	S4
Sovitec France SaS	M81
So-Wa Textile Co. Ltd.	V18
Specialinsert Srl	C56
Specialty Materials Inc.	**TBD**
Specialty Products Co.	G43
Spheretex	M44
Spintech Ventures	TBD
Spinteks Tekstil Insaat San. Tic. AS	TBD
Spolek Pro Chemickou a Hutní Vyrobu, AS (SPOLCHE)	W56
Staubli	G73
Strativer Hutchinson Group	G56
Sulzer Mixpac AG	J73
Sumitomo Corp. Europe Ltd.	TBD
Suragus GmbH	T66
Swancor Ind. Co. Ltd.	R19
Swisstex France SaS	TBD
Synervia	V20
Synthesites Innovative Technologies	TBD
Syrgis Performance Initiators AB	J26
Taian Jingwei Fiberglass Products Co. Ltd.	TBD
Taishan Fiberglass Inc.	H44
Taiwan Electric Insulator Co. Ltd.	M52
Taizhou Europ Mould & Plastic Co Ltd	TBD
Taizhou Huangyan Shuangsheng Plastic Mould	N50
Tartler GmbH, Ingenieurbüro	TBD
TCI (Technique Composite Industrie)	V78
TCR Composites	M55
TE Wire & Cable	**W71**
Techmill	M37
Technical Fibre Products	K52
Techni-Modul Engineering	Y38
Technobasalt - Invest LLC	TBD
Technobell Ltd.	T25
Technocampus EMC2	V20
Techstrand	Q39
Tecnedit Edizioni	TBD
Teijin Aramid	H63
Teillage Vandecandelaere SaS	M83
Telene SaS	D61
Ten Cate Advanced Composites	**R46**
Terruzzi Fercalx SpA	S29
Teufelberger GmbH	M72
Teximpianti Div. Di Vitrex SpA	H12
Texkimp Ltd.	TBD
Texmer GmbH & Co. KG	X58
Thermwood Corp.	G43
Thiot Ingenierie	TBD
Thomas Technik + Innovation	TBD
Tiodize Co. Inc.	G43
Tisstech	M77
TITK	J8
Toho Tenax Europe GmbH	G58
Top Glass SpA	G26
Topcut-Bullmer GmbH	G3
Topocrom GmbH	X56
TPRC	R57
Trelleborg AEM	W80
Trima Spol sro	N75
Trützschler Nonwovens GmbH	Y72
Tubecarbone.Com	P
Tubus Waben GmbH & Co. KG	S55
U.S. Embassy Paris Commercial Service	F43/ G43
Ube Industries Ltd.	Q65
Uchida Co Ltd.	TBD
Umeco	**T50**
Unicarbon	Q55
Unique Textile sro	R73
Universal Star Group Ltd.	TBD
Universite Picardie Jules Verne	TBD
University of Delaware	G43
Uptex	TBD
Utah Composites Industry	F43
Valmiera Glasfaser AG	P19
Van Wees	C38
VEM SpA	L40
Via Mare	TBD
Victrex Europa GmbH	J16
VISTAGY Inc.	W63
Vitech	TBD
VN Composites	T11
Voetsch Industrietechnik GmbH	W73
Wacker Chemie AG	TBD
Waukesha Foundry Co. Inc.	P76
Web Industries	**L55**
Web Processing M C Ltd.	TBD
Weber Manufacturing Technologies Inc.	**P70**
Wells Electronic Materials (Shanghai) Co. Ltd.	TBD
Wessex Resins & Adhesives Ltd.	K56
West Virginia Development Office	D52
Wickert Maschinenbau GmbH	Z58
Wihag Composites GmbH & Co. KG	U32
Wirtschaftsforderung Sachsen GmbH	T66
Wolfangel	M40
Xperion Aerospace GmbH	TBD
Yangzhou Xinyang Technology Development Co. Ltd.	TBD
Zaklady Chemiczne Organika-Sarzyna SA	R8
Zhejiang Chengrudan New Energy Technology Co. Ltd.	Q56
Zhejiang Double Fish Plastics Co. Ltd.	TBD
Zhongfu Shenying Carbon Fiber Co. Ltd.	T26
Zlbm Muehlenbein KG	TBD
Zodiac Aerospace	TBD
Zoltek Corp.	T31
Zotefoams Plc	TBD
Zünd Systemtechnik AG	G23

BIG PARTS? BIG TOOLING BREAKTHROUGH

BY GINGER GARDINER



Source: ÉireComposites

Electrically heated carbon fiber/PEEK/ceramic tooling and powdered epoxy resin system could revolutionize production of large composite aerospace structures.

Faster, more reliable large-part cure

Built using alternating layers of ceramic and carbon fiber-reinforced PEEK, with integrated electrical heating elements, this tooling produced a well-consolidated and fully cured 12.6m/41-ft long thermoplastic composite wind blade. This cut away blade root section (inset) shows how the carbon fiber/PEEK/ceramic composite tooling produces a one-piece blade with no gluelines.

The goal: Build a one-piece wind turbine blade. No adhesive lines. Molded in one shot. *And* with a two-thirds reduction in cycle time. *Impossible*? Not anymore. Not only has ÉireComposites Teo. (County Galway, Ireland) achieved this goal, but in developing the completely new molding solution required to process large thermoplastic composite structures at 200°C/392°F, it also has opened the door to new thermoset materials that might provide thermoplastic benefits without the cost typically associated with processing thermosets. Even better, the system promises to transcend many limitations inherent in autoclave and oven-cure processes used in the fabrication of large carbon fiber-reinforced thermoset parts in aerospace and other industrial applications.

The winding road

In 2008, ÉireComposites claimed it would achieve a two-thirds reduction in large wind blade cycle time by using its patented MECHTool (Mold Efficient Cooling and Heating) technology to form components from fiber-reinforced cyclic butylene terephthalate (CBT) thermoplastic resins (Cyclics Corp., Schenectady, N.Y.). CBT is unique in that it processes similarly to thermosets and, under heat, exhibits water-like viscosity that promotes resin flow and wetout in infusion processes, yet exhibits thermoplastic properties (toughness and resilience) when cured (see "Learn More," p. 41).

That R&D program, called GreenBlade, included partners Mitsubishi Heavy Industries (MHI, Nagasaki, Japan) and Ahlstrom Glassfibre (Helsinki, Finland). Ahlstrom supplied the unidirectional fabric used in the spar cap and webs, and the 0°/90° biaxial fabric for the skins. According to Patrick Feerick, joint managing director of ÉireComposites, each of the various components (shell, spar cap, webs) was laid up and envelope-bagged separately, taking approximately five hours, and final assembly and processing required six hours. "This means that one production mold can yield a blade in six hours while component layup is carried out separately, in parallel, cutting production time significantly," says Feerick.

Initially the company used cast-aluminum tooling, to which flexible metal electrical-heating tape was adhered by embedding it into high-temperature epoxy resin (see "Patented MECHTool System," p. 38). However, the epoxy resin did not have sufficient thermal durability to withstand repeated cycling up to 200°C/392°F. So the epoxy resin was replaced with a ceramic cement paste, resulting in efficient tooling capable of withstanding many hundreds of cycles to 200°C. Despite the improvement, ÉireComposites saw two problems with this approach: (1) the prohibitive cost of metal tooling larger than 5m/16 ft in any dimension, and (2) the coefficient of thermal expansion (CTE) mismatch between the metal tooling and the composite part, which results in large thermal strains (expansions) and significant problems as part dimensions increase to those of today's full-size wind blades.

ÉireComposites' 2009 and 2011 patents document how the company solved this problem: It replaced metal tooling altogether and formed the tool from an aluminosilicate-type ceramic cement, which offers low CTE, density, thermal mass and electrical conductivity. This material also becomes rigid at 60°C/140°F, enabling tooling to be built on inexpensive patterns. It was removed from the pattern after this initial lower-temperature cure and then processed to full temperature (200°C to 400°C or 392°F to 752°F) via a freestanding postcure.

Although it solved many problems, the ceramic brought with it a challenge of its own: low tensile strength. The company attempted to improve tensile properties first with glass fiber reinforcement, but it was not able to reach either the desired fracture toughness or thermal stability necessary to process very large parts. The solution: use carbon fiber (CF) as reinforcement and a high-performance thermoplastic polymer, polyetheretherketone (PEEK), to act as an adhesive between the carbon fiber and the ceramic.

Carbon ceramic tool build

Tool fabrication begins with a pattern. In the case of a 12.6m/41-ft wind blade, metal tubing serves as the longitudinal stringer, and plywood ribs define the pattern's shape. Standard epoxy tooling paste is applied over the stringer and ribs and, after cure, it is machined to net dimensions. Following prep with a release agent, the pattern is coated with a high-temperature, vacuum-tight sealant layer, followed by alternating layers of cement and fiber-reinforced polymer. After three such iterations, electrical heating elements are embedded within a ceramic layer, followed by a final iteration of composite and ceramic. ➲

Source: ÉireComposites

Molding massive thermoplastic structures

The MECHTool (Mold Efficient Cooling and Heating) system is currently used to manufacture reinforced thermoplastic catamaran hulls up to 4.57m/15-ft long.

TABLE 1

Tool size (m²)	Estimated cost of ceramic composite tool (€)	Estimated cost of Invar tool (€)	Oven investment (€)	Savings over Invar + oven (€)	Autoclave investment (€)	Saving over Invar + autoclave
4.0	50,000	60,000	30,000	45%	100,000	74%
8.0	90,000	120,000	45,000	45%	400,000	85%
16.0	170,000	250,000	65,000	46%	900,000	85%
130.0	1,500,000	3,000,000	1,000,000	62%	7,000,000	85%

TABLE 2

Tool size (m²)	Electric units required to run new tooling (kW/hr)	Electric units required to run Invar tooling in an oven (kW/hr)	Savings over Invar tooling + oven	Electric units required to run Invar tooling in an autoclave (kW/hr)	Saving over Invar + autoclave
16	384	1,050	63%	1,500	85%

Source: ÉireComposites

Integral heating speeds ramp-up to cure

After three ceramic cement and carbon fiber/PEEK layers, electrical heater elements are embedded within a ceramic layer, followed by a final iteration of composite and ceramic.

After initial cure at 60°C/140°F, the tool is removed from the pattern and post-cured at 200°C/392°F to fully cure the ceramic cement. However, for tooling using carbon fiber/PEEK reinforcement, a one-time temperature cycle to roughly 400°C/752°F is required to fully melt the thermoplastic and ensure a good bond between the thermoplastic, carbon fiber and ceramic. The in-plane CTE measured for a tool at least 15 mm/0.6 inch thick is less than 5.0 x 10^{-6}/°C, which, according to ÉireComposites, is generally accepted as a "matching value" for most glass and carbon fiber composites. The heat-up rate is controlled by varying the electric power to the heating tape. Using an electrical wattage density of 10 KW/m², suitable for processing thermoplastic composites, this type of tool surface can be brought to 200°C in less than 10 minutes.

This tooling system produced a well-consolidated and fully cured 12.6m/41-ft, 600-kg/1,323-lb glass-reinforced CBT wind blade, with a fiber volume fraction of 50 percent. Feerick claims this is the largest high-fiber-volume thermoplastic composite structure ever manufactured in one piece.

Thermoplastic to thermoset

With a workable system in place, however, ÉireComposites then faced two practical barriers, both to do with scale. For one, the entire 5 million to 6 million lb/yr output of Cyclics' CBT plant in Schwarzheide, Germany, would be consumed by just one product line if any of the major wind turbine OEMs adopt the technology. Cyclics would have to add capacity at the cost of hundreds of millions of dollars. Secondly, Feerick recalls, "We also did not really think we could get all the

SIDE STORY

Patented MECHTool system

Galway, Ireland-based ÉireComposites' patented MECHTool (Mold Efficient Cooling and Heating) system was developed to replace traditional ovens in a number of thermoplastic molding processes. A heating system is built on the B-side of a standard metal or composite open mold, with electrical heating elements divided into zones. Each zone is controlled separately, enabling heat to be applied directly to the location where it is needed. Channels constructed on top of the heating system allow a high volume of conditioned air to be blown over the mold for rapid cooling. MECHTool was developed for heating and cooling molds with very large surface areas. This system is currently used to manufacture a range of products, including bus bumpers and catamaran hulls from Owen's Corning Composite Materials' (Toledo, Ohio) Twintex material. The MECHTool system became the basis for the large composite tooling technology described in the main article, where instead of applying the heating system to an existing mold, it was embedded into the wall of a high-temperature ceramic composite tool as it was constructed. ÉireComposites says MECHTool continues to be an option for molding components that do not exceed the current size limitations of metal tools.

way to creating a one-piece blade via a one-shot process that was easily repeatable on an industrial scale." Each of the components (e.g., spar cap, shear web, shell half) had to be enveloped in a sacrificial vacuum bag to preserve its shape. "We had to have the force of the vacuum to hold each blade part's shape while we processed the resin," he says. The bag film was chosen to be compatible with the CBT and did not affect the properties of the final structure.

The limited CBT supply forced ÉireComposites to look at other materials. The company realized it could use completely new thermoset systems, in particular heat-activated epoxy and polyester systems that exist as solid powders at room temperature. These systems are also completely free of volatile organic compounds (VOCs), have no special storage requirements and an indefinite shelf life, are not sensitive to moisture, and require a shorter dwell at their 180°C to 200°C (356°F to 392°F) cure temperatures than other out-of-autoclave (OOA) materials. By reducing the wattage density to 2 KW/m^2, ÉireComposites' new molding system could provide a ramp-up more suitable for processing thermoset composites, achieving 200°C within approximately 80 minutes.

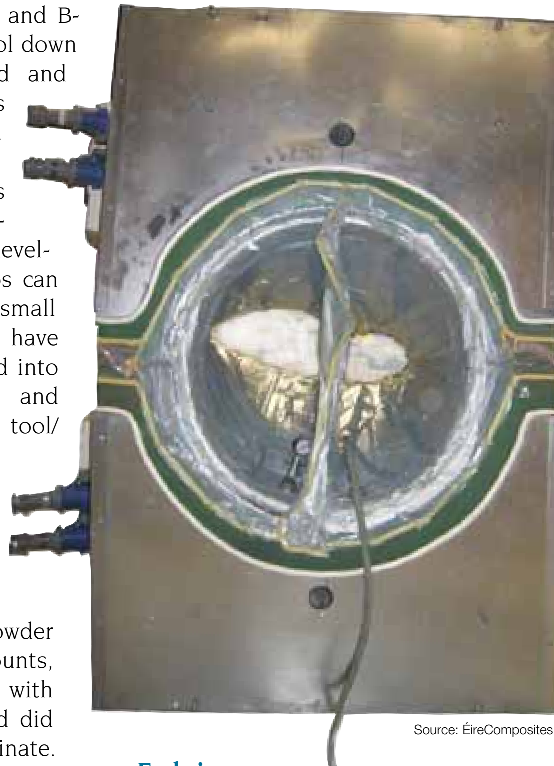
QA for powder coating

ÉireComposites uses a powder-distribution technology from Germany that is able to control the fiber-volume fraction by adjusting the amount of applied powder, says Feerick, "like a powder coating thermoset prepreg line." Used to make thin epoxy- and polyester-skinned panels for the transportation and building industries, the powderized matrix, like CBT, has a very low viscosity when activated by heat. During debulk and final processing, vacuum pressure forces the matrix down into the fibers, but unlike with infusion, where the matrix must travel long distances, the powderized matrix must travel only through the thickness of one ply. "We have done significant testing to investigate fiber impregnation, laminate consolidation and properties," says Feerick. "Micrographs show excellent results, with void contents of 1 percent or less."

The powder epoxies require an eight-hour processing cycle time. Feerick explains that cycle-time reduction is limited by the 70-mm/2.8-inch thick laminate: Because the risk of uneven material temperatures between the A- and B-sides is high, ramp up and cool down must be carefully controlled and monitored, which lengthens the cure cycle time somewhat. But Feerick contends that when layup is automated, this technology rivals the most advanced OOA techniques yet developed. Skins, stringers and ribs can be laminated in parallel on small inexpensive tools (parts only have to see 100°C/212°F); prestaged into easy-to-handle, solid pieces; and then placed inside the final tool/standalone processing system — an electrically heated CF/PEEK/ceramic with built-in cooling.

Seamless success

"When we switched to the powder epoxy technology," Feerick recounts, "we found that the bags used with CBT were not compatible and did negatively affect the final laminate. This is when we changed our approach and took advantage of the fact that this material is solid at room tempera-



Source: ÉireComposites

End view

A closed mold for a wind blade section, ready for heating up to 200°C/392°F.

Thick-section cure

This blade root section was made in one shot, using powdered epoxy at 180°C/356°F, complete with molded-in root inserts for the bolts that connect the blade to the turbine hub.

ture." CBT cannot be prestaged, but the thermoset powder matrices can.

"With the powder epoxy technology, we use a heated vacuum debulk to produce solid preforms that can be assembled like a jigsaw puzzle and then processed at final temperature to produce a seamless wind blade," Feerick says. First, the laminate for each piece is hand layed; then a vacuum bag is applied and the laminate is heated under vacuum to 100°C/212°F. "We can do this in minutes," he points out, "and it allows the epoxy matrix to flow into the fibers." The parts are cooled and the vacuum bag is removed, leaving solid preforms that are easily assembled within the final production tooling. "We then place all of these parts — root, spar cap, shear web and blade shell halves — into the CF/PEEK ceramic composite main production tool, apply [a] vacuum bag to the whole structure and heat the tooling to 180°C, melting all of the pieces into a single structure with no joints or glue lines."

The webs and spar caps consolidate into each other, as do the shell halves and root, with no gap fillers or adhesives required. Feerick notes that this is exceptional: "With the traditional method of building composites, it is very hard to build large structures without having gaps."

Can the epoxy preforms, like thermoplastics, really result in a homogeneous composite where the parts meet? "We have checked the bonds at the leading and trailing edges, for example, which have an overlap, and," he asserts, "have found no reduction in the bond here, with properties that are the same as in the body of the blade shell."

This changes the game, and not only for wind blades. "We see this technology as viable for *any* large composite structure," says Feerick. This includes wind turbine nacelles, truck bodies and other parts that would have insufficient properties with hand layup and take too long to process in prepreg, and so must be made by resin transfer molding (RTM). "We are offering the properties of prepreg but at an overall cost similar to RTM."

Aerospace applications?

Further, compared to the aerospace industry's optimum tooling solution, Invar, ÉireComposites claims that its tooling system could yield an investment savings of 45 to 62 percent if an oven is used, and 74 to 85 percent vs. an autoclave (see Table 1, p. 38). And the ceramic composite tooling, unlike Invar, is not limited by the size of the CNC machining centers used to shape it (currently a maximum 22m/72 ft by 6m/20 ft envelope).

Feerick asserts that the ceramic composite tooling is limited only by the logistics of getting it to the production site, and it can be manufactured onsite if necessary. However, Invar tooling has an extremely long useful life. ÉireComposites' technology is still in development, but Feerick believes, based on initial testing, that lifetimes of 500 and 1,000 cycles at 200°C should be easily achievable. He explains, "The technology has been proven up to 1,000 cycles and continues to operate without any degradation of the materials. The expectation is that it will have a lifetime of several thousand cycles."

Although reinforcements must first be coated with the epoxy powder, Feerick contends that "cost-wise, it is not anything like prepregging because it is much easier and faster. This converted material is lower in cost than traditional prepreg." He adds that the properties of these epoxies are very similar to those qualified for use in aerospace structures.

"Our technology is suitable for OOA thermoset processing, which is something being sought after and used in aerospace right now," he notes. "Aerospace manufacturers could use this tooling technology to process currently qualified epoxy aerospace prepregs without an autoclave and significantly reduce their cycle time." Feerick estimates that up to 40 percent savings could be possible, with the limiting factor being the specific material's required minimum heat-up and cool-down times. Feerick also predicts that manufacturers could drop their energy consumption and associated costs (see Table 2, p. 38).

Revolution: Phase II

Feerick also sees applications of high-temperature thermoplastics in the technology's future. "Because the wind industry was our initial target, we did not need to process at temperatures above 300°C [572°F]. But now we are looking to increase our long-term, repeatable tooling operating temperature to that required by the more advanced thermoplastics used in aerospace." He explains that the heating elements and ceramic materials have operating temperatures of 700°C to 800°C (1292°F to 1472°F), but the ceramic is slightly porous, requiring a vacuum-tight seal. "This is the material that currently limits us," notes Feerick. "The current material we are using is good for 300°C, but we are working now to prove out new systems with much higher temperature capability." ■

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Read more about the GreenBlade program in "Wind blade manufacturing, Part II: Are thermoplastic composites the future?" *HPC* November 2008 (p. 50) or visit http://short.compositesworld.com/h0HiZLMC.

Carbon fiber market: GATHERING MOMENTUM

All signs point to increasing demand from many market sectors. Will capacity keep pace?

BY SARA BLACK

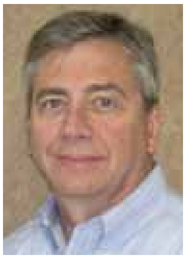
Source: REpower

Wind energy: Top carbon fiber market

This Repower 5M (5-MW) wind turbine (Repower Systems AG, Hamburg, Germany), one of the largest active in the world, features blades built with hybrid glass/carbon fiber reinforcements. A trend toward use of carbon fiber to optimize strength-to-weight in the ever-more-massive blade structures is expected to keep the wind energy segment firmly in place as — by far — the largest consumer of carbon fiber in the world.

Chris Red

Tony Roberts



Jim Stike

Dr. Nirav Patel

While the chill of global recession persists, a subtle change has occurred in the carbon fiber marketplace. *Confidence* was evident at CompositesWorld's annual Carbon Fiber 2011 conference in Washington, D.C. (Dec. 5-7), at the Washington Marriott hotel. With The Boeing Co.'s composites-intensive *Dreamliner* already in service and the Airbus A350 XWB almost ready for final assembly, demand for aerospace-grade fiber is already strong. Yet, according to conference presenters, *industrial* demand is surging (see "Side Story," p. 44). A few years ago, Carbon Fiber conference participants celebrated small victories in new niche applications and discussed the "what ifs" on the horizon. Now the horizon isn't so distant — fiber consumers are emerging in droves from nearly every conceivable market sector, ready to try carbon composites in a huge range of applications. Forget the *What's a composite*? question; it's now *Is there enough fiber to sustain growth*?

"The conference presentations ranged from the industry's early days to its growth potential in the wind energy, automotive and aerospace sectors," reports event cochair Tom Haulik, carbon fiber sales manager at Hexcel (Stamford, Conn.). "There is a strong sense of opti-

Table 1	PAN-based Carbon Fiber, Manufacturer Nameplate Capacity, metric tonnes		
	2011	2015	2020
Toray	19,000	21,000	21,000
Zoltek	14,000	16,000	18,000
Toho	13,900	13,900	13,900
Mitsubishi	13,000	13,000	13,000
China (combined)	9,200	10,000	10,000
Hexcel	7,500	8,500	8,500
Formosa Plastics	8,000	8,000	8,000
SGL Carbon	7,900	10,000	10,000
Cytec	2,300	4,000	4,000
AKSA	1,800	3,600	4,000
Hyosung	<1,000	2,000	8,000
Others	<1,000	1,000	1,100
SABIC	0	1,500	5,000
Totals:	97,500	112,500	124,500

Table 2	PAN-based Carbon Fiber, Manufacturer ESTIMATED ACTUAL Capacity*, metric tonnes (based on 2011 market share)		
	2011	2015	2020
Toray	19,000	23,000	31,000
Zoltek	14,000	17,000	23,000
Toho	13,900	18,000	22,000
Mitsubishi	13,000	15,000	20,000
China (combined)	9,200	11,000	18,000
Hexcel	7,500	9,500	12,500
Formosa Plastics	8,000	9,000	11,500
SGL Carbon	7,900	14,500	18,000
Cytec	2,300	5,000	6,000
AKSA	1,800	5,000	6,000
Hyosung	<1,000	3,000	8,000
Others	<1,000	1,500	5,000
SABIC	0	1,500	5,000
Totals:	97,500	133,000	186,000

Table 3	Carbon Fiber Demand Forecast, Aerospace and Defense, metric tonnes		
	2011	2015	2020
Commercial aircraft	4,300	7,910	13,290
Military fixed-wing	500	770	1,000
Rotorcraft	370	400	460
Business Aircraft	240	590	720
General Aviation	600	1,000	1,250
Jet engines	380	1,660	1,930
Space and launch	450	520	550
Carbon-carbon	160	240	500
Total:	7,000	13,100	19,700

Table 4	Carbon Fiber Demand Forecast, Industrial, metric tonnes		
	2011	2015	2020
Wind energy	12,280	37,600	67,400
Oil and gas	1,380	2,700	10,650
Molding compounds	5,750	7,700	10,170
Industrial rollers	450	700	820
Pressure vessels	1,650	7,250	12,520
Automotive	2,700	4,000	5,600
Civil infrastructure	1,900	2,900	3,900
Pultrusion	1,300	2,200	3,710
Misc. energy	180	500	1,520
Medical/prosthetics	240	320	440
Tooling	2,000	2,700	3,960
Total:	29,830	68,570	120,690

Table 5	Carbon Fiber Demand Forecast, Consumer, metric tonnes		
	2011	2015	2020
Sporting goods	6,840	7,180	7,860
Marine	800	1,600	2,190
Misc. consumer	1,380	2,010	3,240
Total:	9,020	10,790	13,290

Table 6	Total Global Carbon Fiber Demand, metric tonnes		
	2011	2015	2020
Aerospace	7,000	13,100	19,700
Industrial	29,800	68,600	120,690
Consumer	9,000	10,790	13,290
Total Demand:	45,800	92,490	153,680

*Represents Roberts' estimates of actual capacity (*greater* than manufacturer's estimated nameplate in Table 1 by 2015) if suppliers maintain current competitive market share in response to growing demand (Table 6).

mism as carbon fiber manufacturers put heavy investment in new innovations that will increase capacity and performance, while providing solutions for cost-sensitive applications."

Chris Red, principal of Composites Forecasts and Consulting LLC (Gilbert, Ariz.), and industry consultant Tony Roberts of AJR Consulting (Lake Elsinore, Calif.) were on hand again, joined this year by David Service, CEO of Bluestar Fibres Co. Ltd. (Grimsby, U.K.). Red, as always, delivered a wealth of information and data on market *demand*, and Roberts discussed the flip side of fiber *capacity*. Service offered insight into the critical link in the supply chain — fiber precursor.

Carbon fiber supply

On the supply side, there have been several new entrants since the 2010 conference, including Hyosung (Gyeonggi-do, South Korea), that are on course to manufacture 8,000 metric tonnes (17.637 million lb) by 2020, estimates Roberts. SABIC (Riyadh, Saudi Arabia), he believes, will produce 5,000 metric tonnes (>11 million lb) by that same date, in Saudi Arabia and Italy, through its partnership with Montefibre SpA (Milan, Italy). He also called out Turkish manufacturer AKSA (Istanbul, Turkey), which recently formalized a joint venture with The Dow Chemical Co.'s (Midland, Mich.) European entity on Dec. 20, 2011, to commercialize carbon fiber products worldwide. Also new is a Toray Industries (Tokyo, Japan) line in South Korea; a Moses Lake, Wash., facility opened by SGL Automotive Carbon Fibers (Wiesbaden, Germany); Alabuga Fiber LLC (Tartarstan, Russia), which produces 1,500 metric tonnes (>3.3 million lb); and, he believes, an Iranian plant of unknown capacity. According to Roberts, "Every country wants a carbon fiber plant," and more announcements will come from South Korea and South America before year's end.

Roberts also reported that 18 companies in China claim to produce polyacrylonitrile (PAN) with a combined nameplate (maximum) capacity of 9,200 tonnes (nearly 20.3 million lb). Plants range, in theory, from 30 to 1,500 metric tonnes (66,140 to 3.3 million lb). Yet sources inside China say actual production is between 500 and 1,000 metric tonnes (1.1 million and 2.2 million lb). To address the glaring discrepancy, Roberts compared the reported 2010 market demand for carbon in China (9,785 metric tonnes/21.572 million lb) against reported imports of carbon fiber into that country (8,737 metric tonnes/19.262 million lb). The comparison of imports to demand shows that internal production is not yet meaningful. "The Chinese are currently working on improving the quality and performance of their fiber," he stated.

Roberts' data (Table 1) show PAN-based carbon fiber nameplate capacities. Actual output varies from 60 to 70 percent of nameplate numbers because the process efficiency is dependent on fiber size (the lowest efficiency/greatest knockdown occurs for the smallest fiber sizes). This year Roberts did not break out small-tow and large-tow quantities because, in his view, producers will shift to more large tow to meet industrial demand. And he points to Mitsubishi Rayon Co. Ltd.'s (MRC, Tokyo) new P330-series 60K fiber as "changing the goal posts" for large-tow fiber. "Small-tow dominance is fading. The new large-tow MRC fiber sets a new industrial fiber standard in terms of performance."

SIDE STORY

CF 2011: Comment on end-markets and initiatives

Representatives from the U.S. Department of Energy (DoE) and Oak Ridge National Laboratory (ORNL, Oak Ridge, Tenn.) teamed up to present "Low-Cost Carbon Fiber for Emerging Energy Applications." The two government entities have been trying for many years to make carbon fiber from lignin, polyethylene, polyolefin and other nontraditional precursor materials. ORNL's **Dr. Cliff Eberle** described his group's carbon program, consisting of development of viable precursor materials, development of the technology for converting the precursor into fiber, development of design and manufacturing capabilities for high-volume composite applications and, finally, finding ways to transfer the technology to industry partners.

The group recently purchased a new manufacturing line from Harper International (Lancaster, N.Y.) that is highly flexible and able to handle any type of precursor material in either fiber or web format, says Eberle, with output of up to 25 metric tonnes (55,116 lb) annually (based on 24K fiber). The line can produce fiber sizes from 3K to 80K and is also capable of bicomponent and hollow fibers. It should be producing fiber in early 2013. ORNL also will install a melt-spun carbon fiber line in the coming year.


Warren

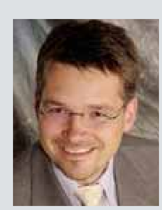
ORNL's field technical manager for transportation materials research **David Warren** spoke next, identifying the impacts that low-cost carbon fiber will have on the automobile industry. Although carbon composites can be used to achieve a 10 percent mass reduction in a vehicle, for a 7 percent increase in fuel economy, carbon fiber involves the greatest cost penalty for that improved performance when compared to other materials, such as aluminum or magnesium. On the other hand, he said, carbon composites can deliver excellent crash protection, if they are well designed. Warren estimates the market demand for carbon fiber at 158 million lb (71,668 metric tonnes) per annum. He added that because high-volume applications are so cost-sensitive, fiber with moderate performance, even less than 250 ksi/6.89 MPa, will fill the bill.

Keynoter **Bruno Beral**, head of Structure Policy and Development for Engineering Structure at Airbus (Toulouse, France), spoke about the aircraft manufacturer's composites innovations, both current and future. His main point was that "no single material can do it all," and he made it plain that Airbus wants to maintain the competition between metal and composites to get the best of both materials (for more, see Scott Stephenson's comments on Beral's presentation in "From the Podium," on p. 15). On Beral's wish list are a new matrix material — not epoxy — that performs better than existing resins, plus more automation in manufacturing, and elimination of fasteners. Beral says the next phase of aircraft design also will demand multifunctional advanced materials, including composites, that integrate structures and systems — that is, true smart structures.

Dan Ott, the global strategic account manager for advanced composites at Web Industries Inc. (Marlborough, Mass.), gave an interesting presentation on the topic of slit prepreg tape. Web is a well-qualified supplier of slitting services, that is, taking rolls of unidirectional prepreg and slitting it to very tight tolerances for use on automated tape laying machines and in fiber placement processing. As you might expect, the process is tedious, with very little room for error, and requires a lot of effort to produce a quality product, because of the "organic" nature of carbon fiber. After describing how his company deals with fiber alignment, production speeds, splicing (if allowed), fiber fuzzing and more, and the care that's required, he raised some interesting questions. To increase use and acceptance of carbon fiber and composites in general in wider applications, would the industry be willing to accept slightly lower tolerances for higher throughput? Can machine designers work with material suppliers to avoid issues during layup? Can the industry develop a wider range of materials, including out-of-autoclave prepregs or thermoplastics, for broader application?

Vanni Tomaselli, a research and development engineer with Waves S.A. (Luxembourg) spoke about the huge emerging market for carbon fiber in marine compressed natural gas (CNG) transport and storage. Noting that oil and gas engineers are the most conservative, his company's focus is on large pressure vessels for the CNG market. In one hypothetical case, a ship outfitted with 143 carbon fiber/epoxy pressure tanks — each 9m/29.5-ft long with a 14.5-metric-tonne (nearly 31,970-lb) capacity — could carry 50 million ft^3 (almost 1.416 billion liters) of natural gas and could consume 3.4 million lb (1,542 metric tonnes) of 30K carbon fiber. (The required amount of carbon fiber might increase or decrease depending on the scenario and if less stringent safety factors are employed in making the pressure vessels.) Tomaselli reported that his company is working with Spencer Composites (Sacramento, Calif.) on filament winding technology and noted that a tank project will begin in early 2012.

Dieffenbacher North America's (Windsor, Ontario, Canada) sales manager **Christian Fais** made an argument for high-pressure resin transfer molding (RTM) of composite parts. The process developed by Dieffenbacher uses a proprietary preforming step and very high mold pressure (60 to 100 bar or 870 to 1,450 psi), resulting in improved impregnation, shorter cycle time and excellent surface properties. Fais reports that the company is close to a total part cycle time of only three minutes, making the process feasible for automotive parts.


Fais

Finally Roberts believes that given predicted demand, fiber manufacturers will actually have to produce *more* than their stated nameplate quantities over the next decade, as reflected in Table 2. In fact, in comparison to Red's demand figures (to come), Roberts thinks demand will exceed capacity as soon as 2015, if growth remains robust.

One way of bolstering fiber supply to meet coming demand could come via recycling efforts. Jim Stike, CEO of Materials Innovation Technologies (MIT, Fletcher, N.C.), presented a paper on his company's progress in making carbon fiber recycling profitable. His firm has developed a range of products that incorporate recycled fibers, from mats to slurry-molded custom shapes. Stike's customers include Trek Bicycle (Waterloo, Wis.).

Carbon fiber demand

Red's theme for the demand side of the equation was "an industry evolving into high-volume processing." As this implies, he believes the key to further market expansion — he predicts 235 *percent* growth by 2020 — is continued development of high-rate manufacturing methods. Beginning with the aerospace and defense markets (Table 3), Red sees a trend toward greater composites use, with carbon composites becoming the predominant aircraft structural material. He expects that jet aircraft engines, turbofans and turbojets, will provide strong opportunities for composites, particularly in the engine hot sections. "There's a carbon/ceramic material coming that will be adopted for engine structure," he revealed. He also cites more use of automated manufacturing in engine components for growing adoption. Space vehicles (orbital and launch) is another key market for big growth over the next decade, in Red's view.

Once again, Red's data clearly identified the wind turbine blade sector as the largest industrial consumer of carbon, and once again, Red predicted that wind energy will continue to grow significantly and wind farm refurbishment will provide a huge opportunity. As he did past conferences, Roberts disagreed, cautioning that the massive wind developments seen recently in China will slow due to grid connectivity issues. However, a presentation by Dr. Nirav Patel (GE Energy – Advanced Sourcing Engineering, Greenville, S.C.), seemed to support Red's view (see note in "Learn More," this page). GE Energy is increasing carbon fiber use, not only in blades but in other business areas. Patel said 24K or greater standard-modulus carbon fiber will form primary structures of *1,600* next-generation 48.7m/160-ft blades for its new 1.6-100 turbines. He also claims that in 2012 alone, GE Energy expects to consume ~3,000 metric tonnes (~6.6 million lb) of carbon fiber.

Greater use of carbon fiber now appears inevitable (*235 percent* growth by 2020). How that demand will be met is unclear.

Red is less enthusiastic than some about the adoption of carbon composites in cars: "It will be another decade before we see massive adoption of composites in automotive." Representatives from Oak Ridge National Laboratory (ORNL, Oak Ridge, Tenn.) were more optimistic, in a preconference seminar on low-cost carbon fiber for the automotive market. ORNL is actively involved in several partnerships, including one with Dow, to explore the market for automotive carbon fiber made from alternative precursors, including lignin, olefin and polyethylene. And recent announcements of partnerships between carmakers and carbon producers portend an upsurge in automotive composites: General Motors (Detroit, Mich.) recently teamed with Teijin Ltd. (Tokyo, Japan) to push a part-per-minute process for carbon-fiber car parts, and a BMW and SGL Technologies GmbH (Wiesbaden, Germany) joint venture is already producing carbon fiber for two of BMW's forthcoming battery-powered BMW electric commuter cars (see "Learn More").

Red forecasts that aerospace demand (Table 3) will increase by 180 percent during the next decade, with 95 percent of that fiber delivered as unidirectional or woven prepregs. For industrial components (Table 4), he predicts 310 percent growth, with energy applications dominating the space. Consumer applications (Table 5), a more mature market, will grow a mere 47 percent in the next 10 years. By 2020, says Red, industrial uses will dwarf all others, with wind energy, by far, the largest in that space.

Is there enough precursor?

The final presenter, Service, painted a less rosy picture of the coming decade. After he explained the fiber production process, including the various precursor solvent technologies employed, he reiterated Roberts' and Red's predictions that carbon fiber sales will increase to 80,000 or 90,000 metric tonnes (176.4 million to 198.4 million lb) by 2015, with major growth in the industrial sector. But he warned that because 2.2 lb of precursor is required to make 1 lb of carbon fiber, nearly *300,000* metric tonnes (661.4 million lb) would be required in 2015, almost *double* the output of 2011. Although global acrylonitrile production per year is 6 million metric tonnes (13.227 billion lb), the chemical is a necessary feedstock for *many* products. Further, its cost is steep, currently between $1,500 and $3,000 per metric tonne, which directly affects precursor cost. He estimates that it will take about $30 million to build a plant capable of 1,000 metric tonnes (2.2 million lb) of PAN precursor annually, and he's unaware of any near-term plans for big new facilities or plant expansions. Given these precursor, realities, Service estimates that the per-pound cost is now $10.90, up 32 percent compared to 2001.

So ... on to maturity, or a return to cyclical downturns for lack of capacity? That question has been asked every year for decades, Roberts points out. Greater use of carbon fiber now appears inevitable. How that demand will be met is unclear, but emerging fiber producers, fiber recycling efforts and fibers from alternative precursors might yet and forever smooth the ups and downs of the industry. ■

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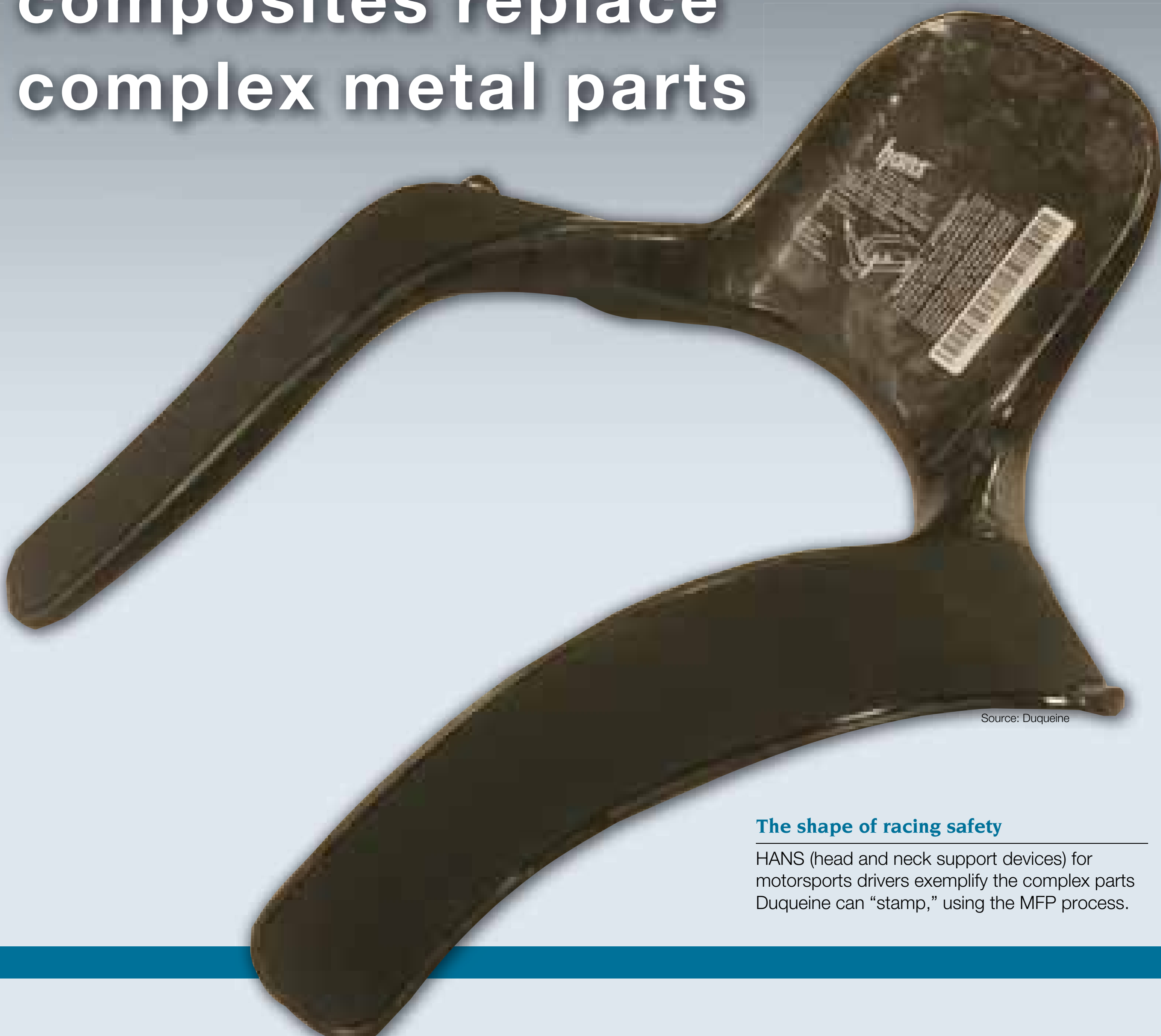
Read this article online at http://short.compositesworld.com/BuE63eRz.

Read more about Patel's keynote presentation in "From the Podium," in *HPC's* sister publication *Composites Technology* (*CT* February 2012, p. 5) or visit http://short.compositesworld.com/tiRTetgL.

Read more about the BMW/SGL automotive carbon composites partnership in *"SGL Automotive Carbon Fibers plant's two fiber lines in production," HPC* November 2011 (p. 17) or visit http://short.compositesworld.com/6u9fjkUc.

FORGED composites replace complex metal parts


Source: Duqueine

The shape of racing safety

HANS (head and neck support devices) for motorsports drivers exemplify the complex parts Duqueine can "stamp," using the MFP process.

Powerhouse manufacturer's high-pressure compression molding process forms prepregged CFRP components with forged-metal properties.

BY GINGER GARDINER

Brothers Gilles and Vincent Duqueine began their careers as composites mavericks by pioneering the use of a CFRP monocoque body/chassis in place of previous tubular frame designs in Formula 3 (F3) open-wheeled racecars. Although they parted ways in the 1980s, both continued as innovators in composites manufacturing, ultimately putting together vastly different enterprises. Vincent formed Carbone Forgé (Lentilly, France), which focuses on high-pressure molding of net-shape complex and hollow parts, including a proprietary "fusible core" washout mandrel technology (see the "Forging variations" side story, at right). Meanwhile, Gilles built the Massieux, France-based Duqueine Group, which has become a composites manufacturing powerhouse.

With an annual turnover of €45 million ($58.9 million USD) in 2010, Duqueine employs more than 600 people, including as many as 80 engineers, at its 28,000m^2 (300,000-ft^2) of production and R&D facilities spanning five worldwide sites: Duqueine Rhône-Alpes (headquarters in Massieux and Reyrieux, France), Duqueine Atlantique (Nantes, France), Duqueine Romania (Timisoara, Romania) and, scheduled to open this year, Duqueine Mexico (Quérétaro, Mexico).

Accomplished in a variety of composites processes, including hand layup, semi-automated layup, resin transfer molding (RTM) and infusion mold-

SIDE STORY

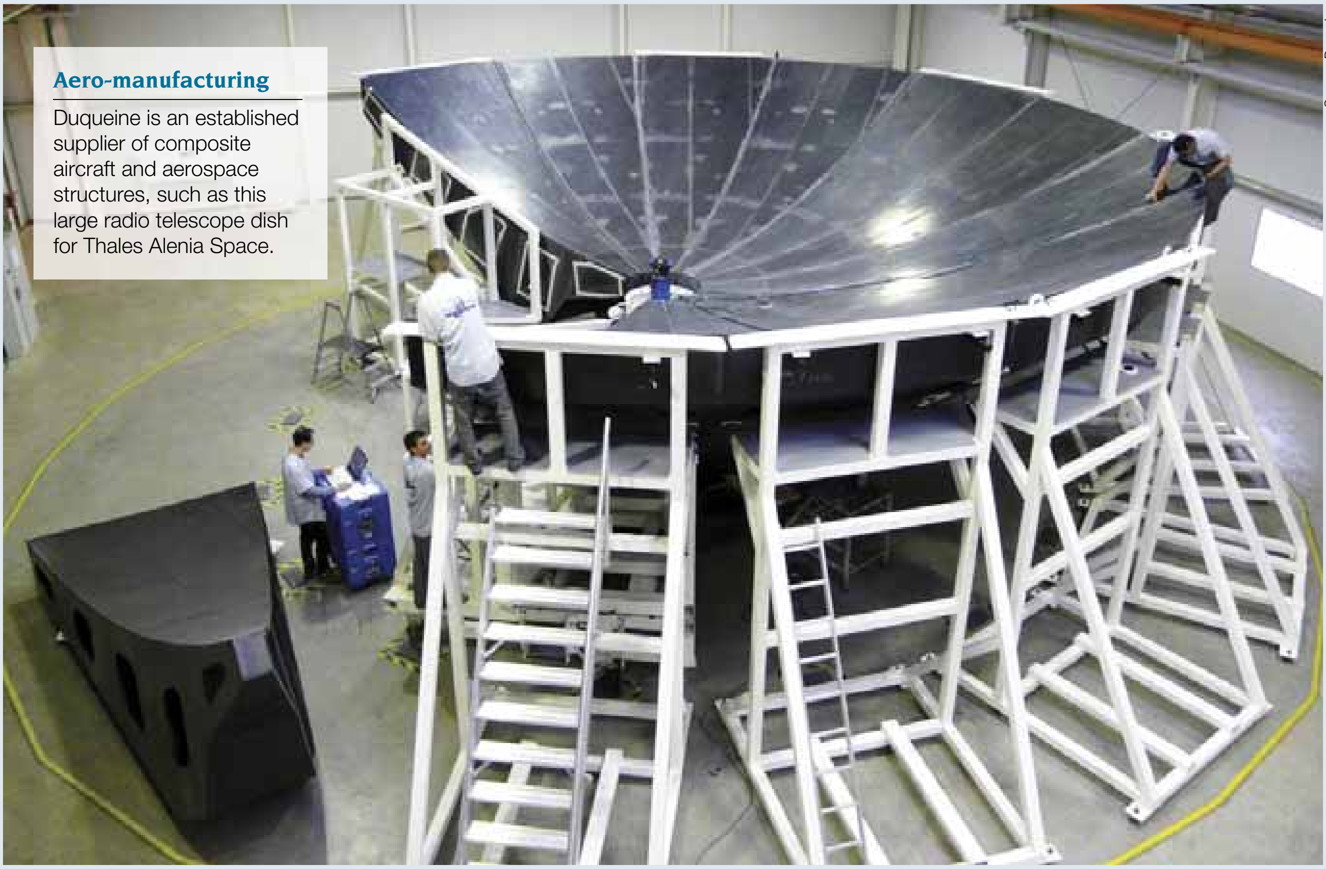
Forging variations

Developed in parallel to the Duqueine Group's (Massieux, France) MFP process, the high-pressure molding process used by Lentilly, France-based Carbone Forgé is described by Vincent Duqueine as "enabling forging of composites, similar to that done with metals."

Carbone Forgé describes itself as part of a group of European aerospace companies that is focused on improving the understanding of in-mold behavior of composite materials and simulating that behavior to create one-piece parts with complex geometries. In U.S. patent 6,884,379 B1, Vincent describes it as similar to the MFP process in that it uses prepreg between matched metal molds, but unlike his brother's process, it does not use prepreg *bundles*. Like the Duqueine Group's MFP process, however, the Carbone Forgé method also works with thermosets and thermoplastics to produce aerospace components and parts for sporting goods and other industries, including bicycle parts for Look Cycle International (Nevers, France). Carbone Forgé uses a proprietary mandrel made from "fusible core" washout material.

How the two brothers' companies market their processes also differs widely: Vincent, at Carbone Forgé, works more with fabricators to license and adapt his process to their production needs, while Gilles has focused the Duqueine Group toward direct mass manufacturing.

The Duqueine Group's VP/business development manager, Jérôme Aubry, who has worked with the brothers for many years, says the Carbone Forgé process works better with flat and long parts. For hollow parts, it incorporates meltable mandrel technology, which Aubry does not see as practical for the high-volume parts pursued by the Duqueine Group.

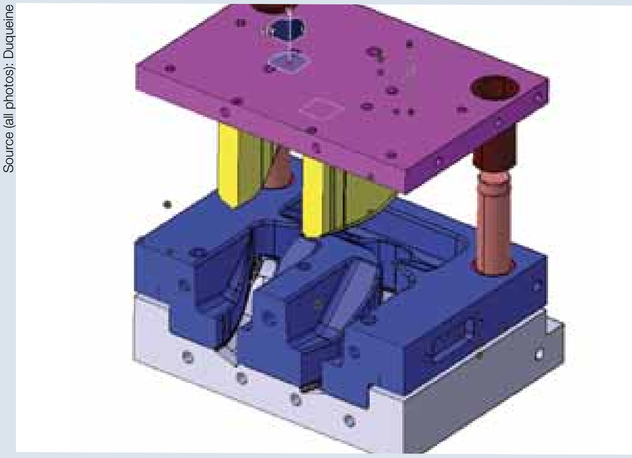


Source: Duqueine

Aero-manufacturing

Duqueine is an established supplier of composite aircraft and aerospace structures, such as this large radio telescope dish for Thales Alenia Space.

Source (all photos): Duqueine



Step 1

The part and mold are designed and materials tested for flow to meet specified properties.

Step 2

Thermoset or thermoplastic prepreg is cut into bundles or “beams” and then processed into a premix. (Shiny appearance is due to lighting angle.)

Step 3

The premix is then cut into a preform.

Step 4

The preform is placed into the matched metal mold (in this case, bell-shaped adjusters used in Thales Alenia radar units).

Step 5

The mold is closed and temperature and pressure are applied to cure the part.

Step 6

The finished, net-shape part, after removal from the mold.

ing, Duqueine has progressed from a Tier 3 to a Tier 1 supplier to Dassault Aviation (Paris, France), EADS Sogerma (Rochefort, France) and Safran Group (Paris, France). It recently won three large work packages for the Airbus A350 XWB — including fuselage frames, window frames and engine air-intake panels — and reportedly leads the world in carbon fiber-reinforced plastic (CFRP) bicycle wheels, producing 40,000 per year for parts manufacturer and Tour de France partner Mavic (Annecy, France). Duqueine also is an established supplier of aircraft interior subassemblies and ducting; industrial structures, such as large radio telescope dishes for Thales Alenia Space (Cannes, France); and head and neck support (HANS) devices.

Now compulsory for most motor sports, including NASCAR, CART and Formula 1, a HANS device is worn by

> HANS structures, made primarily of CFRP, are one type of a growing number of unusually shaped parts made with the MFP process.

race car drivers to reduce the risk of head and neck injuries, such as basilar skull fracture, during a crash. It features a U-shaped neck support that sits at the back and base of the skull, with two arms that curve over the shoulders and lie flat along the pectoral muscles of the chest, all formed as one piece. HANS structures, made primarily from CFRP, are one example of a growing number of unusually shaped parts Duqueine is making using its counterpart to Carbone Forgé's high-pressure molding process. Called the MFP process, the patented method of "forging" net-shape parts from "prepreg bundles" was developed over a decade to duplicate in reinforced plastics parts that previously had been forged from metals.

HANS structures are in demand. The unit volume is fairly high, from 10,000 to 16,000 per year. This, along with its recursive shape, scalable section and high property requirements, makes it an ideal part for MFP manufacturing. According to Jérôme Aubry, VP/business development manager for Duqueine, "We have a range of HANS parts made from classic prepreg using special inflatable mandrel technology, and then also another range made with MFP." He adds, "MFP allows us to achieve high-series and low-cost production while maintaining exacting property specifications."

Forging composites

The basic technology involves compression stamping preforms that are made from random bundles of chopped thermoset or thermoplastic prepreg. "The main advantage of MFP is that labor is reduced to almost nothing," explains Aubry. "You put material into the mold, close the mold and produce a finished part." This is one factor in MFP's ability to reduce a composite part's price by up to 30 percent without sacrificing mechanical properties. There is also no waste of raw material, which is significant because CFRP raw material is expensive.

"We put 100 percent of the material into the mold," says Aubry. "With normal prepreg manufacturing methods, you can reach 20 percent of raw material as waste due to cutting." Because MFP is basically compression molding, it inherently has the ability to manufacture net shapes, with no further trimming, which also drastically drops labor and cost. "With MFP, we are able to manufacture complex shapes not possible with traditional prepreg," Aubry relates. "Also, inside the mold, you can have finish on all of the surfaces for a given part."

However, the tradeoff is the upfront investment required to accurately design and fabricate the mold. Says Aubry, "The key aspect to the process is to understand the flow of raw material for each type of resin and fiber, and to specify the temperature, pressure and speed to optimize this." He adds, "When we make flow operations, we have to take care to ensure the proper percentage of resin to fiber [fiber volume]. This is a key parameter of our initial design work and is partly determined by the shape of the part and partly by the type of raw material and its flow behavior." Aubry adds that MFP consistently produces very good resin-to-fiber distribution, even when part shapes are complex, and he claims that the process can also handle variations in thickness without any extrusion of resin from the parts.

Using a variety of raw materials, Duqueine has used MFP to produce part types as diverse as bicycle cranks, the block door island for the Airbus A340, the bell base for Thales antennae and parts for medical and railway applications. The company has developed MFP design and processing expertise not only with traditional thermoset resins, but also thermoplastics, including polyamide (PA12), polyphenylene sulfide (PPS), polyetherimide (PEI) and polyetheretherketone) PEEK.

Duqueine has used MFP to produce part types as diverse as bike cranks, radio antennae and parts for medical and railway applications.

This great variety is possible because the prepreg used for MFP is first cut into *bundles*, ranging in size from approximately 50 mm by 8 mm (2 inches by 0.3 inch) to as little as 25 mm by 8 mm (1 inch by 0.3 inch) for very small parts. The bundles are what permit deformation and material flow in the mold. "The raw material must follow the shape of the part in the mold," Aubry explains. "This makes the part much more similar to forged metal parts vs. cutting prepreg to form a part, which results in a weaker structure." He continues, "The overall mechanical properties we can achieve are thus improved for parts with complex geometry."

Producing a HANS device

After the HANS part and its mold have been designed, using CATIA V5 R18 supplied by Dassault Systèmes (Paris, France), the process is optimized for the resin and fiber combination. Duqueine then prepares the part preform. Aubry says, "We buy prepreg and cut it to make the premix and preforms, or we can buy HexMC." The latter is a high-performance sheet molding compound made by Hexcel (Stamford, Conn., and Lyon, France) from 50-mm/2-inch long carbon fibers in a matrix of 250°F/120°C-cure epoxy resin. Hexcel has one grade for industrial applications and another for aerospace. Duqueine is familiar with both, having worked with Hexcel on a wide variety of applications for more than 10 years. For non-HexMC materials, two cutting machines, adjustable to the size of bundles, cut the thermoset or thermoplastic prepregs. "We do cut the HexMC, but only to produce the preform [shape]," Aubry notes. "It is not necessary to cut it into bundles because that has already been done."

Depending on the part shape, the cut prepreg bundles are either manually layed into preforms or formed using a semi-automated process. The part preform is then placed into the mold, and temperature and pressure are applied to achieve cure. The temperature is typically the same as that used for aerospace-grade CFRP prepregs, roughly 120°C to 180°C (250°F to 350°F). However, much more pressure is applied than is typically used in an autoclave, which helps to produce parts without porosity. "Though the pressure depends on the geometry, we generally work with a pressure of 100 bar [1,450 psi] on the material," says Aubry. Parts usually cure within 15 minutes (for industrial applications), depending on their thickness, and require no further trimming. The type of press used depends on the geometry of the part, ranging from 30 to 300 tons, which allows Duqueine to produce parts up to $0.5 m^2/5.4 ft^2$.

> MFP is the production weapon for Duqueine's latest campaign: replacing complex metal structures with "forged" composites.

Future directions

MFP is the manufacturing weapon for Duqueine's latest target: replacing complex metallic structures with composites that approach the high physical properties and precision of forged metal, but with the low unit cost of compression molding.

Applications in MFP's crosshairs are aerospace parts, including aircraft seat fixations, or attachment rails — which are currently machined aluminum — and other aluminum or titanium seat parts such as handles, elbow rests and brackets. Their complex geometry makes them difficult to make in prepreg, but they are high in volume. The investment in the matched metal mold is justified by the greater volume. The material used is typically steel (e.g., 40CMD8, a hardened French alloy tool steel) to ensure sufficient resistance to the high compression pressures.

According to Aubry, "MFP also reduces the weight of the parts because we produce the same mechanical properties, keeping the same shape as the original aluminum." The MFP part retains the same volume, but at a lower density — the density of aluminum is 2.6 to 2.7g/cm³ (0.09 to 0.1 lb/in³), and the density of CFRP using MFP is 1.6g/cm³ (0.06 lb/in³). Mass reduction is one of the principle drivers behind the use of the MFP process. Reportedly, MFP also is well suited for parts like clips, and it can make shapes with *evolutions of sections* (e.g., a box beam that "evolves" into a curved or tapered section), which are not easily reproduced in autoclaved prepreg.

However, the process is not well suited for CFRP fuselage frames. "We are manufacturing fuselage frames for the A350," says Aubry, "and [standard] prepreg is well adapted to these because of the long length of the parts." Clips can pose a problem, however; there may be 6,000 per plane, but there also could be 5,000 part reference numbers. In other words, there is no single clip produced at high volume, but rather a great number of unique parts. The cost of the MFP mold is difficult to justify for a few of each type of clip.

Duqueine already has developed expertise in the aircraft seating sector. using more traditional processes, and has produced roughly 700 composite seat shells, thus far. The company also is working on other programs with EADS Sogerma for the Airbus A380. Duqueine is quite comfortable with the seating supply chain's tight product specifications and timelines, delivering one seat part — from design to full-scale production — within eight months. MFP, the company says, will give the company increased capabilities in seat-part production and will do much to help Duqueine meet seat cost targets as well.

Currently Lyon, France, is the center of MFP technology, but Duqueine hopes to develop programs that will enable the company to extend MFP capability to its newest 3,000m² (32,300-ft²) production facility in Mexico, which is scheduled to come online this year. Gilles Duqueine explains that the Mexico MFP operation will help the company avoid a too-heavy reliance on any one market or single client, adding that the Mexico operation will be exclusively dedicated to the markets of the Americas and capable of both design and fabrication of composite parts and subassemblies. ■

> Duqueine has developed expertise in the aircraft seating sector. MFP will do much to help the company meet seat-production cost targets.

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Read this article online at http://short.compositesworld.com/48IYK9KT.

For news about Carbone Forgé, see "MBDA pushes for maturation of Carbone Forgé technology," at http://short.compositesworld.com/LnruUaMd.

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March 5-7, 2012 SpeedNews 26th Annual Commercial Aviation Industry Suppliers Conference
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March 13-15, 2012 Composites Manufacturing
Mesa, Ariz. | www.sme.org/composites

March 22-23, 2012 11th World Pultrusion Conference
Istanbul, Turkey | www.pultruders.com

March 26-27, 2012 SAMPE Europe Conference (SEICO 12)
Paris, France | www.sampe-europe.org

March 27-29, 2012 JEC Europe 2012
Paris, France | www.jeccomposites.com

March 27-29, 2012 2012 Aircraft Interiors Expo
Hamburg, Germany | www.aircraftinteriorsexpo.com

April 16-19, 2012 EWEA 2012
Copenhagen, Denmark | www.ewea.org/annual2012

April 24-26, 2012 Techtextil North America
Atlanta, Ga. | www.techtextilna.com

May 21-24, 2012 SAMPE 2012
Baltimore, Md. | www.sampe.org

May 24-26, 2012 KOMPOIST COMPOSITE ISTANBUL
Istanbul, Turkey | www.kompoist.com

May 28-June 1, 2012 MCM-2012 – XVII International Conference on Mechanics of Composite Materials
Riga, Latvia | www.pmi.lu.lv/html/Confinf.htm

June 3-6, 2012 WINDPOWER 2012
Atlanta, Ga. | www.windpowerexpo.org

June 12-13, 2012 6th CFK-Valley Stade Convention
Stade, Germany | www.cfk-convention.com

July 22-28, 2012 ICCE-20
Beijing, China | www.icce-nano.org/

Aug. 6-9, 2012 AUVSI's Unmanned Systems North America 2012
Las Vegas, Nev. | www.auvsishow.org

CW **Sept. 25-27, 2012** High-Performance Resins 2012
Seattle, Wash. | www.compositesworld.com/conferences

CW **Oct. 22-25, 2012** CompositesWorld 2012: Materials, Markets, Manufacturing
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APPLICATIONS

Thermocouple innovation shortens autoclave setup for stringers/frames

Source: TE Wire & Cable

ATK Aerospace Structures (Clearfield, Utah) produces, among other structures, carbon fiber/epoxy stringers and frames for an aircraft application that demands high-rate production. Until recently, one of ATK's production cycle challenges was in preparing the parts for the autoclave. ATK process engineer Nate Lodder says it could take one-and-a-half to two hours to attach and document the required thermocouple channels.

The composite structures, for an unidentified customer, require two to five thermocouples per part, with anywhere from 20 to 60 parts per cure. ATK identified this process through its LEAN initiatives as an opportunity to significantly reduce cycle time. The thermocouple system in use was proving to be a significant bottleneck in meeting the goal to produce more parts per autoclave each month.

In August 2011, ATK began to trial an alternate thermocouple system from **TE Wire & Cable LLC** (Saddle Brook, N.J.) called AccuConnect. A multi-circuit thermocouple extension harness, AccuConnect consists of a multi-circuit threaded connector (male or female) coupled with a customer-specified number of thermocouple wires (type J or K). The other end of the AccuConnect harness terminates with a customer-selected individual thermocouple connector or a multi-circuit connector.

"We selected an AccuConnect system with six channels in one connection and gold plating on all connectors. This dramatically reduced the number of connections needed vs. the previous system of one channel per thermocouple," Lodder says. "Implementing the AccuConnect system reduced the overall thermocouple setup time to just 20 minutes." In conjunction with its use of AccuConnect, ATK has developed a barcode system that enables the company to quickly scan and document thermocouple layout.

The simplified documentation is not trivial. When one channel was represented by one thermocouple, ATK had to use specialized layout software to ensure that connections were associated with the appropriate parts and structures.

Since August, Lodder says, "ATK has run the AccuConnect thermocouples through more than 80 cure cycles in three different autoclaves." He reports that signals have been accurate and problem-free and expects that ATK will expand AccuConnect use to its other autoclaves.

Software enables submarine shipyard's composites-for-metal effort

Composite materials have slowly earned their way onto submarines for decades. For its part, Howaldtswerke-Deutsche Werft GmbH (HDW, Kiel, Germany) has increased composites usage on its vessels by 10 percent per year since 2008, thanks to FiberSIM software (**VISTAGY Inc.**, Waltham, Mass.).

A submarine source since 1897, HDW is the leading builder of non-nuclear-powered submersible vessels and the only one to offer fuel-cell-powered submarines. Three years ago, the company set out to use more composites, targeting vessel weight reduction and improved hydrodynamic stability, stealth and sonar transmission. Cutting costs via parts consolidation was another big goal, says Marc Tillmanns, HDW's lead composites engineer. But the worry was that large, thick parts would be difficult to produce and document accurately.

When HDW looked for a software solution to reduce the risk of using composites for a greater range of thicker parts, FiberSIM enabled its engineers to develop initial designs more quickly and to better understand the impact of design changes because design is better linked to manufacturing: "FiberSIM takes a lot of the worry out of the process by capturing the details of the final layups and verifying specifications with the software's design verification tools," says Tillmanns. Accurate flat patterns can be produced quickly, showing dart and splice placement, without trial and error, which previously wasted time and materials on the shop floor. Further, the software tracks the variety of materials that HDW uses and enables precise calculation of material weight and resulting inertial properties of the parts. The company also employs FiberSIM's Laser Projection software to reduce layup errors and labor during part layup, using a projection system built by **SL-Laser Systems LP** (Charlotte, N.C.).

Source: HDW

With FiberSIM, HDW has added a variety of glass and carbon parts on its Class 214 submarines, including the complete upper deck, keel covers, tower sail fairings (cusps), propeller blades and rudders. More parts will follow, including a torpedo storage rack. "FiberSIM allows us to convert from metal to composite faster and minimizes the risk by verifying information before we get to the manufacturing floor," says Tillmanns. "There's no question that composites will grow in prominence for us, going forward." ■

NEW PRODUCTS

Integrated AFP/ATL machine

MAG IAS (Erlanger, Ky.) on Jan. 25 announced the introduction of the new GEMINI Composite Processing System, a manufacturing solution capable of switching within minutes from automated fiber placement (AFP) to automated tape laying (ATL). The company says the system cuts the capital cost of duplicate equipment, infrastructure and labor traditionally needed to install and maintain separate AFP and ATL systems, making it suitable for aerospace tier suppliers who must have AFP/ATL flexibility but require cost economy. The first GEMINI system has already been purchased by Alliant Techsystems (ATK) and will be installed at ATK's Iuka, Miss., facility. The system's modular vertical gantry design can be configured for multiple work zones or extremely long parts and uses MAG's VIPER AFP head and either MAG's CHARGER or **Forest Liné's** (Granby, France) ATLAS ATL heads. Head docking cradles outside the work zone allow offline setup or maintenance of the heads while the machine continues to produce parts; the head changeover takes only two minutes.

The gantry design accommodates fixed floor-mounted or rotation-type tooling in outer mold line (OML) or inner mold line (IML) configurations. Available in various widths and any length, the gantry setup can be had with x-axis rails for either on-floor (surface mount) or in-floor (flush mount) installation. A new wireless control pendant provides freedom and convenience for technicians who work with the system. The system also can support multiple gantries.

Head designs: VIPER AFP heads handle tow widths of 3.2, 6.4 and 12.7 mm (0.125, 0.25 and 0.5 inch), producing fiber bandwidths of up to 203.3 mm/8 inches. They feature independent control over *feed*, *clamp*, *cut* and *restart* for up to 16 individual tows of composite prepreg slit tape, enabling automated on-the-fly adjustment of the fiber bandwidth, controlled placement of fibers around changing contours, and precise configuration of openings. MAG's CHARGER tape laying head applies 75-, 150- or 300-mm (3-, 6- or 12-inch) carbon/epoxy tape in any orientation and number of plies, at speeds of up to 100 m/min (4,000 ipm). The head allows side loading of tape rolls up to 300 mm/12 inches wide and 650 mm/25.6 inches in diameter. Common hardware permits layup of 150-mm/6-inch and 300-mm/12-inch wide tape with minimal changeover time. The head design also features integrated ultrasonic laminate cutting, cutter depth-setting assistance and dockable inkjet marking. Its infrared heating system is said to provide faster response and greater precision than air heating. The Forest Liné ATLAS tape head dispenses precut rolls of material that were made on the Forest Liné Access system. Along with the precut roll of tape, the ATLAS head can carry simultaneously bulk rolls of material 150 or 300 mm (6 or 12 inches) wide, allowing a part to built up using both precut rolls of material and material from bulk rolls of tape. **www.mag-ias.com; www.forest-line.com**

Compact 3-D scanner

New from **Capture 3D Inc.** (Costa Mesa, Calif.) is the ATOS Compact Scan, designed to provide accurate scans with detailed resolution at high speeds. It combines the latest ATOS Blue Light Technology and software into a compact package. According to the company, the scanner is manufactured with high-quality components, and the lightweight and compact sensor can be used in various applications and environments, especially in narrow and confined areas. It reportedly can quickly measure and provide the data necessary to inspect design models, prototypes, castings, molded parts and other structures, including vehicles (exterior and interior). **www.capture3d.com**

VOC filtration system

Environmental C&C Inc. (Scotia, N.Y.) has introduced to the composites manufacturing industry a fluid bed concentrator (FBC) system designed to remove styrene and other volatile organic compounds (VOCs) from shop air. In the system, process air from odor sources is directed to a fluidized bed adsorber. The air passes through adsorber sieve trays, fluidizing beaded activated carbon (BAC) adsorbent distributed on the trays. The mixing of beads with the contaminated air enables transfer of VOCs and odors to the adsorbent pores. The orientation of the multiple sieve trays provides countercurrent VOC removal, thus optimizing efficiency. Clean air exits the adsorber top, while spent BAC collects in the bottom hopper. Heat is applied by one of several options to vaporize and separate VOCs from the adsorbent. As VOCs are released in highly concentrated form (desorbed), a low flow of carrier gas conveys the concentrate out to a final treatment device. The system reportedly is mechanically simple, with a small footprint and low weight. Features include high VOC concentration ratios that result in low energy use during final treatment as well as discrete adsorption and desorption sections that eliminate thermal cycling and energy waste. Further, the unit is compatible with existing VOC-control systems, making it simpler to expand current capacity. **www.environmentalcc.com**

Bio-based prepregs

Bio-chemical specialist **Elmira** (London, U.K.) has released a range of prepregs that feature bio-based resins, available with a selection of reinforcements, including carbon fiber, E-glass fiber and naturally derived fiber alternatives. These materials are suitable for a range of processes and curing requirements, exhibiting good resin flow and cured-laminate quality. The company claims the materials provide curing characteristics and, in postcure use, thermal stability and mechanical performance comparable to conventional epoxy-based prepregs, and they also impart increased impact strength along with better water and chemical resistance. **www.elmira.co.uk**

Peel ply for structural bonding

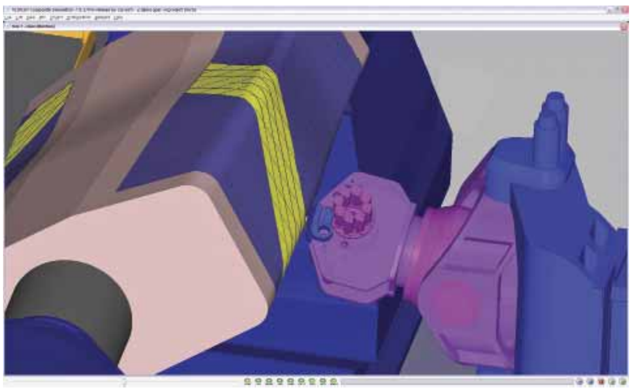
Diatex SaS (Rhone Alpes, France) has introduced DIATEX 1500 EV6, a new peel ply developed for structural bonding of composite materials. It is said to be suitable for use with all adhesives or adhesive films, works with all resins and has no storage constraints. It can be supplied with porosity calibration for use in vacuum infusion processes, and it functions at any curing temperature. Samples from every peel ply batch are subjected to interlaminar fracture toughness (G1C) and slotted single lap-shear strength tests to validate bonding. Manufactured under an EN9100 certificate, the product is said to be qualified for aerospace applications. **www.diatex.com**

Elastomer composites

Cabot Corp. (Boston, Mass.) has launched the Transfinity line of elastomer composites, described by the company as a "new class of materials" that improves elastomer durability and delivers "transformational" performance improvements in wear-resistance and vibration-isolation applications. Products in the line are composites made from elastomer latex and reinforcing particles, such as carbon black. The products are produced in a patented process, which creates composites that are stronger than conventional elastomer materials. Applications include rubber pads or tracks on military vehicles, automotive suspension components that reduce vehicle weight and improve fuel economy and protective lines for mineral processing equipment. **www.cabot-corp.com**

Programming software: European debut

CGTech (Irvine, Calif.) reported on Jan. 18 that it will introduce to the European market its VERICUT Composites Paths for Engineers (VCPe) at the JEC Europe 2012 show this month (March 27-29 in Paris, France). VCPe



provides the features of the company's established VERICUT Composites Programming (VCP) product, yet it is not configured to program a specific automated fiber placement (AFP) machine. VCPe enables design and production engineers to develop manufacturing strategies for composite parts and test for manufacturability in a virtual environment. At CGTech's stand, visitors will be updated on projects that highlight the implementation and use of machine-independent, offline NC programming software for AFP machines. **www.cgtech.com**

Machining, drilling & tapping systems

MC Machinery Systems Inc. (Wood Dale, Ill.) has introduced the MC Milling line, comprising five series of vertical machining centers and drilling and tapping machines. The MCV Series features general-purpose machining centers with two spindle/tooling system types. The CAT-40 tooling system uses an 8,000-rpm motor; the CAT-50 system uses a 6,000-rpm motor. The DV Series is a general-purpose machine, featuring a 15,000-rpm direct drive spindle and CAT-40 tooling. The DM Series features a 20,000-rpm HSK-A63 spindle, which uses a more rigid and accurate tooling system. The SV Series is built with a heavy-duty box way construction in the x, y and z axes and uses a 10,000-rpm spindle, CAT-50 tooling and hand-scraped box way guides. The TV Series of drill/tap machines feature a 24,000-rpm, high-speed spindle driven by a 5-hp motor. **www.mitsubishi-world.com**

Nondestructive imaging system

Start-up firm **Novitom** (Grenoble, France) reports that it has developed an imaging system that uses the penetrating power of synchrotron photon beams to produce noninvasive, nondestructive analyses of matter, including composite components and structures. The company reports that it can determine, with good detail, the internal structure of products or scientific samples, including chemical and structural data. The technique provides 3-D microscopic reconstructions of matter with what is said to be unprecedented levels of contrast, even with materials that provide low levels of absorption. **www.novitom.com**

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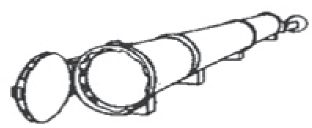

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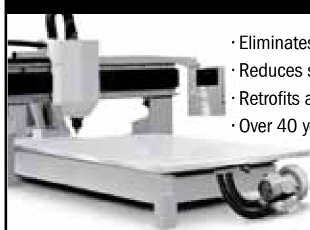

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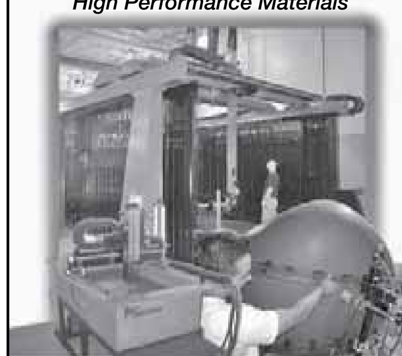

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PRODUCT & LITERATURE SHOWCASE

CUSTOM-ENGINEERED COMPOSITE

North Sails introduces 3D*i* materials and process for structural

As long ago as 3500 B.C., the first boat sails were made by cutting and joining multiple pieces of woven cloth. Most sails are still assembled in a similar — if more sophisticated — manner, typically using woven polyesters. But after 5,500 years, the world of sailing is witnessing the early days of a sailmaking revolution.

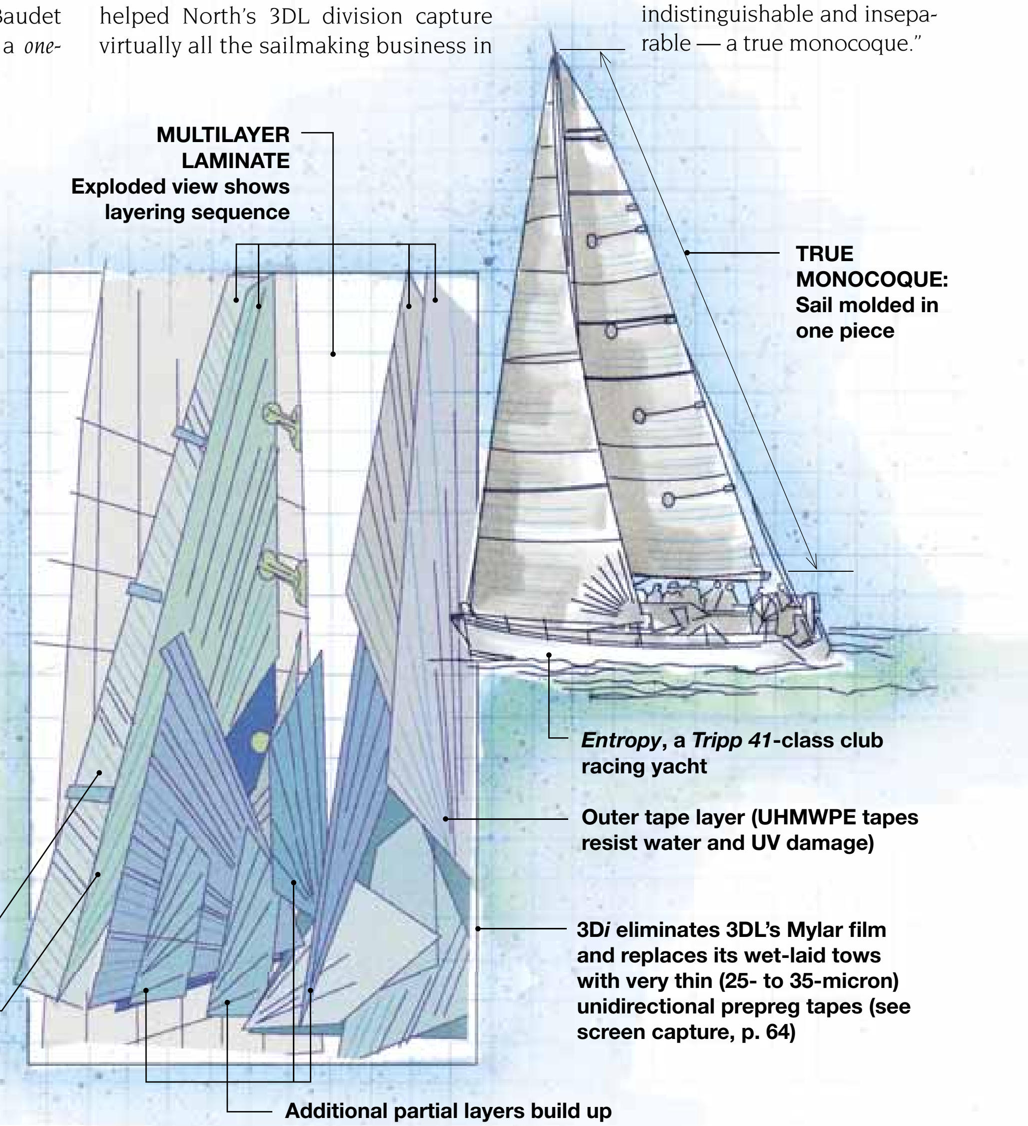
In the early 1990s, Swiss sailors and sailmakers Luc Dubois and J.P. Baudet developed a method for making a *one-piece* sail. Commercialized by North Sails (Milford, Conn.) at its Minden, Nev. facility as the 3DL process, the method makes a sail free of the dimensional inaccuracies and uneven loading that are unavoidable in an assembled sail. The 3DL sail carries fiber tows in the primary load paths (which mainly run corner to corner) laminated between two layers of Mylar film. It helped North's 3DL division capture virtually all the sailmaking business in the top end of yachting's racing and performance-cruising markets (see "Learn More," p. 64).

North has since gone the extra knot to produce sails that are custom-engineered, true monolithic composites. "The surface and structure are now one," explains Bill Pearson, North's director of materials and technology. "The two are fabricated simultaneously, and they are indistinguishable and inseparable — a true monocoque."

NORTH 3D*i* CUSTOM ENGINEERED COMPOSITE SAILS

DESIGN RESULTS

- New sail design replaces previous Mylar-encapsulated, wet-laid fiber tows with a monolithic laminate of prepreg tapes.
- Anisotropic laminate architecture is replaced by a quasi-isotropic structure that better maintains a balanced resistance to stretching in all directions, to best exploit the wind's drive power.
- Automated tape layup enables creation of a one-piece structure that forms a true monocoque.



PERFORMANCE YACHT SAILS

composites that better exploit wind power.

BY DONNA DAWSON
ILLUSTRATION / KARL REQUE

The new concept came from another pair of Swiss sailmakers, Gerard Gautier and Edouard Kessi, who in 2001 sought the Holy Grail of sailmaking: balanced resistance to stretch and compression loads, which translates to less change in sail shape as the boat moves through uneven wave patterns and fluctuating wind pressure. Stretch in the sails, mast or rigging acts as a shock absorber, dissipating some of the available wind power, so stiffer, higher-modulus sails that exhibit greater resistance to stretching are critical. "The more effective modulus a sail has, the more energy created by wind pressure is translated into driving force to power a boat forward through the waves," explains Pearson.

Eventually, Gautier and Kessi came up with a plan to make a soft sail membrane with a fiber architecture *customized* to meet design loads of the sail. North purchased the technology in 2007 and began adapting its 3DL sail molding system to the new vision, under a new name: 3D*i*. It eliminates 3DL's Mylar film and replaces its wet-laid tows with very thin — 25 to 35 microns — unidirectional prepreg tapes.

The "i" is for "isotropic"

Where 3DL is *anisotropic*, exhibiting properties that vary in different axial directions, 3D*i* has the distinct advantage of producing *quasi-isotropic* laminates. "With fiber and, thus, tensile and compressive modulus running in multiaxial directions, instead of just in the direction of the primary loads, the general resistance of the fabric to stretching is much improved," says Pearson. But, he adds, "With fiber now running in all orientations, the sail designer must think about compressive properties and their ramifications in the membrane … and how compressive modulus, off-axis, affects load path performance."

Customers send design files that describe the sail's geometry, flying shape and finishing details to North, where the 3D*i* File Processing Department applies North's own Design Suite of software tools that enable it to virtually sail and test a boat under a variety of conditions before construction.

Source (all photos): North 3D*i*

Three equipped with 3D*i*

The TP52 *Decision* IV (top right) sports a 3D*i* headsail. 3D*i* sails fly fast on this *Tripp* 41-class club racer, E*ntropy* (above). The U.S. entry from PUMA Sailing breaks waves during the 2011 Volvo Open 70 race (bottom right).

North recently used the Suite to design the headsail for the high-performance racing yacht *Decision* IV (see photo above), winner of the IRC East Coast Championship race in Key West Race Week 2009.

The Suite's first tool, Desman, builds a 3-D model of the sail/rig system. Next, its Spine & Spiral software defines the 3-D shape as a molded surface, with its edges and shape adjustable in horizontal and vertical axes. Flow 2006 software then simulates air flowing over the sail, producing a pressure map on the sail's surface. Finally, the Membrain finite element analysis (FEA) program takes data from the Desman model and Flow simulation and applies pressure to the sail/rig combination. As the pressure deforms the sail's surface, Membrain links back to Flow repeatedly to acquire new pressure fields for the sail surface. Initially designed for 3DL analysis, Membrain has been modified to deal with prepreg tapes and to handle off-axis and compressive forces in the membrane in addition to axial load paths.

Sailing on thin tapes

The thin-ply prepreg features spread tows. "We talk about a fiber being 100 percent spread if it is a *single filament* in thick-

Source: North 3D*i*

Screen to tool

This screen capture shows the ply schedule simulation for ATL layup of the *Decision* IV headsail. Each color represents a different ply (inset shows actual layup of corner tapes).

ness, all spread side by side across the width of the tape," Pearson explains. The spread tows are drawn through a covered resin bath, deposited onto backing paper, dried and then slit into narrow tapes, which are rolled onto cassettes that can be loaded onto an automated tape laying (ATL) head. Following a programmed ply schedule, the ATL deposits and cuts layers of the thin tape to build up a multiaxis preform that meets the specified design loads and configuration of the sail.

The preform layers are then transferred to North's unique articulated male molds. Patented by North for 3DL sails, the mold design was modified for 3D*i* sails. Molds are push-button adjustable in three dimensions (an eight-minute process) to match each sail's unique, complex curvature.

Source: North 3D*i*

Inside job

North 3Di's ATL, built in-house, lays prepreg tape for the *Decision* IV headsail.

The different tape layers are joined in a staggered pattern over a release film on the mold, overlapping in a scarf-like joint to ensure consistent sail thickness and strength. A secondary sacrificial film is placed over the top of the layup. The finished laminate is vacuum-bag consolidated and heat cured by a robotic infrared device that adjusts speed and temperature on the fly as it traverses the surface. The *Decision* IV headsail cured in about two hours at 90°C to 100°C (194°F to 212°F).

Stiff, but flexible

Although optimum stiffness/stretch resistance is a primary goal, each sail also must be flexible. North pursues these usually mutually exclusive goals by combining different fiber types and resins to take advantage of the best properties of each. For stiffness, the company employs high-modulus carbon fiber. "Since sails are modulus driven, rather than strength driven, and carbon fiber is the highest modulus material, that's the appropriate material for a high-performance Grand Prix racing boat," says Pearson. Carbon offers the additional benefit of good compressive modulus, aiding in the important goal of balanced distortion resistance.

To counteract carbon's inherent brittleness, North commingles carbon fibers with Dyneema (DSM Dyneema, Geleen, The Netherlands) ultrahigh-molecular-weight polyethylene (UHMWPE) fibers, which add tenacity, durability and breaking strength to the sail membrane and offer resistance to water absorption and ultraviolet light.

The percentage of UHMWPE depends on the desired balance between stiffness and longevity. Pearson says 70 percent carbon is the maximum for acceptable sail durability, so a 70:30 carbon/UHMWPE ratio is typical for a Grand Prix-class sail. "Dyneema is nearly impossible to break, and there is some Dyneema in all 3D*i* sails for this reason," Pearson notes. North maintains a library of about 50 tapes in different weights and fiber blends.

North customized the *Decision* IV headsail to meet its specific performance requirements and chose from the company's library of carbon/UHMWPE tapes to meet requirements — adding specialized tapes as needed. Tapes high in UHMWPE are typically used for the sail surface and the interior corners, which handle grueling loads; up to 15 all-UHMWPE layers are stacked in sail corners, with about 35 more blended with carbon fiber for stiffness. In contrast, only five or six layers of commingled carbon/UHMWPE tape are applied in the sail's center, averaging a 70:30 ratio. Surface tapes, however, are nearly all UHMWPE to take advantage of its water- and UV-resistance. "By carefully choosing the constitution of each layer, a sail designer can prescribe exactly the mechanical properties of the resulting composite [sail]," Pearson says.

Although carbon offers the ultimate in stiffness, for "around-the-world" sails, such as those on the U.S. entry from PUMA Sailing in the 2011 Volvo Open 70 race, North uses Twaron aramid from Teijin Aramid (Arnhem, The Netherlands). Aramid's lower modulus is offset by increased elongation-at-break, giving it the flexibility needed for endurance. But, says Pearson, "It is *more* about inherent brittleness — about how many times you can flex or fold a sail made out of different fibers. If you pinch a dry carbon tow between your thumb and forefinger and aggressively try to break the tow, it will take you about five seconds. When you do the same thing with an aramid tow, two days later you would still be trying to get it to break."

North worked with two resin producers to design two flexible matrices, using proprietary commingled polyester thermoset resins: A softer, higher elongation resin in the tapes for the sail interior and one with higher Barcol hardness for a smooth, abrasion-resistant surface.

Expanding the market

Notably, North designed and built its own tow spreader, prepreg line and ATL, *and* wrote the tapemaking and tapelaying software. All of the 3D*i* manufacturing equipment is housed in a dedicated facility in Minden, near the 3DL plant, and Pearson says business is brisk: 11 molds are now in use, 24/7. ■

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Read this article online at http://short.compositesworld.com/8kX6ogwR.

Read more about sails produced with the 3DL process in "New dimensions in sailing," *HPC* September 2005 (p. 44) or visit http://short.compositesworld.com/hCCasuhE.


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