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MARCH 2013 /Vol. 21 / No. 2

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- Gurit CBS 200: Auto panels in 10 minutes?
- Designing satellite fuel tank for *demiseability*
- CF 2012: Market surplus for carbon fiber?

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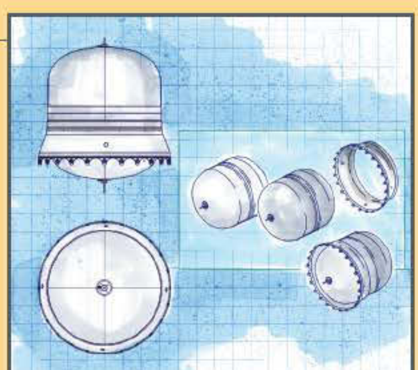
MARCH
volume: twenty-one
number: two | **2013**

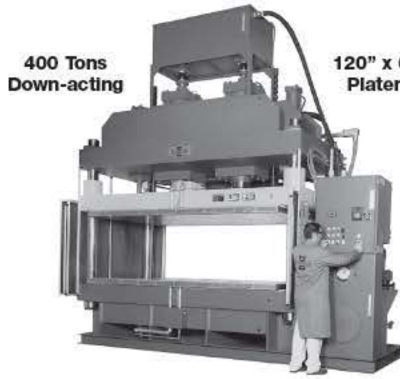
FOCUS ON DESIGN

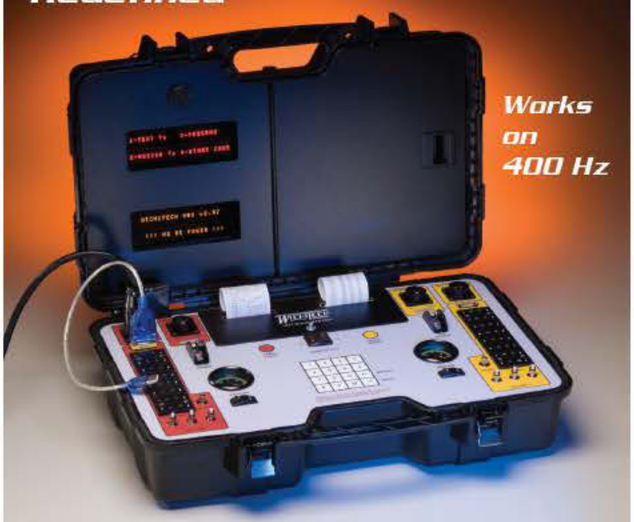


ON THE COVER

With the debut of its 2014 Chevrolet *Corvette Stingray*, General Motors Co. (Detroit, Mich.) became the world's first automaker to use Class A CFRP body panels produced via a new "pressure-press" technology invented by Plasan Carbon Composites (Bennington, Vt.). Built specifically to mold the *Stingray's* CFRP hood and roof, Plasan's plant in Walker, Mich., is equipped with five new "pressure presses" designed and built by Tacoma, Wash.-based Globe Machine Manufacturing Co. (see story on p. 42).

Source: General Motors Co./Photo: © General Motors Co.





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CORPORATE OFFICES

Gardner Business Media Inc.
6915 Valley Ave. / Cincinnati, OH 45244-3029
p: 513.527.8800 / f: 513.527.8801 / www.gardnerweb.com

Group Publisher & *HPC* Publisher — **Richard G. Kline Jr.** rkline2@gardnerweb.com

Marketing Manager — **Kimberly A. Hoodin** kim@compositesworld.com

Art Director — **Jeff Norgord** jnorgord@gardnerweb.com

Graphic Designer — **Susan Kraus** skraus@gardnerweb.com

SALES OFFICES

Midwestern U.S. & International Sales Office
Associate Publisher — **Ryan Delahanty**
rdelahanty@compositesworld.com
p: 630.584.8480 / f: 630.232.5076

Eastern U.S. Sales Office
District Manager — **Barbara Businger**
barb@compositesworld.com
p: 330.239.0318 / f: 330.239.0326

Mountain, Southwest & Western U.S. Sales Office
District Manager — **Rick Brandt**
rbrandt@gardnerweb.com
p: 310.792.0255 / f: 800.527.8801

European Sales Office
European Manager — **Eddie Kania**
ekania@btopenworld.com
p / f: +44 1663 750242

CIRCULATION

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p: 800.950.8020 / f: 513.527.8801 / rjacobs@gardnerweb.com

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EDITORIAL OFFICES

CompositesWorld / PO Box 992 / Morrison, CO 80465
p: 719.242.3330 / f: 513.527.8801 / www.compositesworld.com

Jeff Sloan / Editor-in-Chief
jeff@compositesworld.com / 719.242.3330

Mike Musselman / Managing Editor
mike@compositesworld.com

Sara Black / Technical Editor
sara@compositesworld.com

Lilli Sherman / Senior Editor
lsherman@compositesworld.com

CONTRIBUTING WRITERS

Dale Brosius
dale@compositesworld.com

Ginger Gardiner
ginger@compositesworld.com

Michael R. LeGault
mlegault@compositesworld.com

Peggy Malnati
peggy@compositesworld.com

John Winkel
jwinkel@indra.net

Karen Wood
karen@compositesworld.com

FROM THE EDITOR

jeff@compositesworld.com

Back in 1990, when I graduated from college with a degree in technical journalism, I would have said, accurately and logically, that I was a magazine editor. No more and no less. At that time, of course, the Internet was still more science fiction than fact, and communication technology consisted primarily of telephone (landline), fax, newspaper, magazine, radio and television.

If you were a composites professional back then, you likely read *Advanced Composites* magazine or a similar early industry title (alas, *HPC* did not yet exist), and you attended composites industry tradeshows and conferences to find new technology you could use to manufacture composite parts and structures. If you're nostalgic, you likely look back on those days as simple and straightforward, uncluttered by the digital media landscape. Or, if you've adapted well, you might look back on those days and wonder how anyone got anything done. If you're like me, you probably do a little of both.

Although I still say, 23 years later, that I'm the editor of a technical trade magazine, that doesn't begin to describe all that I do. When pressed, or engaged in a quasi-philosophical discussion about the "future of media," I'll tell you that what I really am — what all of us at *HPC* are — is *information managers*. It's our job to seek, collect and distribute information about composites manufacturing and then present it to our audience (you) in whatever form is most convenient.

The keyword, of course, is "form," because we are no longer mere magazine publishers. Many of you still read the printed magazine, and this is, still, the dominant form, but you might also be reading this in our digital magazine or online at our Web site. You likely also receive our e-newsletter, the *CompositesWorld Weekly*, and you might also follow us on Facebook, Twitter or Linked In.

We are now adding a new form to our communications arsenal, the CompositesWorld Blog. You can find it easily on the home page of the CW site: www.compositesworld.com. The CW Blog will feature short, pithy, creative reports from myself and other *HPC* writers and editors about the goings on in the composites industry — consider the CW Blog our subjective, biased commentary on the news, events, people and technology that are shaping the composites community.

Why a blog? The real upside is its interactive nature. It's not just about what we think. We know that you composites professionals are keen observers of the trends shaping this industry. The blog provides an opportunity to put your interests, insights and intelligence to work. It enables you to chime in with comments of your own about the subjects we explore. You may agree, disagree, add to, embellish, dissect, argue, defend or question as you see fit. You may respond to the comments of others and see how others respond to yours.

Consider the CW Blog our subjective, biased commentary on the news, events, people and technology that are shaping the composites community.

So I encourage you to make haste to the new CompositesWorld Blog and become a part of the conversation. As always, if you have ideas or suggestions to help us serve your information needs better, I'm all ears.

Jeff Sloan

MARKET TRENDS

M&A ACTIVITY IN THE COMPOSITES INDUSTRY: A REVIEW OF 2012 AND THE OUTLOOK FOR 2013

Michael Del Pero is a seasoned investment banker with FocalPoint Partners LLC (Los Angeles, Calif.) who works exclusively with advanced materials companies. He advises them on mergers, acquisitions, divestitures, raising capital, restructuring and strategic planning. He is a regular contributor to *High-Performance Composites* and has chaired the CompositesWorld Investment Forum on numerous occasions. He can be reached at +1 (310) 405-7005 or mdelpero@focalpointllc.com.

As we move toward the end of the first quarter in 2013, there is a fair amount to be positive about. Equity markets are returning to levels not seen since before the Great Recession. Manufacturing activity remains strong (for now, at least). And prospects for continued strength in the mergers and acquisitions (M&A) markets are promising. The political and regulatory environment, however, remains a wild card, and we will be watching closely as discussions about the U.S. debt ceiling evolve.

In the composites industry, 2012 was a moderate year for M&A. We tracked roughly 65 deals involving composites and related end-markets, which is on par with activity in recent years. Although deal activity has been consistent, we feel it is still below where it should be, given the number of companies in the industry. For example, the plastics manufacturing segment (a close cousin to the composites industry) registered more than 350 M&A transactions in 2012. Putting aside the volume of acquisition and divestiture activity, the industry's structure remains highly fragmented. We have observed for some time a growing disparity between large and small companies. In fact, Cytec Industries' (Woodland Park, N.J.) recent acquisition of Umeco Plc (Heanor, Derbyshire, U.K.) reinforces this dynamic.

A prevalent theme in last year's presidential election was that the rich are getting richer as the middle class struggles to achieve upward mobility. We see something similar in M&A. Large players are using healthy balance sheets to grow proactively through acquisitions and strategically position themselves for the long term. But a vast number of small- and medium-sized companies continue to focus on very small niches in the market as their sole basis for long-term growth and prosperity.

Many of these midsize companies have been driven to focus on growing organically in reaction to industry trends and demands. With the ramp-up in transformational composites-intensive platforms in aerospace and recent breakthroughs in automotive composites, the industry has, for the most part, focused on technology development and insertion in recent years. But now that most of those programs have transitioned into production mode, company executives might find themselves having to think a bit more strategically to continue growth.

But what does "strategic growth" really mean? We talk to a lot of entrepreneurs and composites business owners and have found that there is some misconception here. Often, when business owners think of their strategic options, they think it must involve either selling their business or buying someone else's. In many cases this might be the right path, but for some companies it simply isn't appropriate, based on timing, business cycles or personal preference. Strategic growth isn't an either/or proposition. There are a host of tools available to companies that want to grow beyond organic means. These include, among others, nondilutive debt financing for expanding capacity or capabilities, raising minority equity to bring on a partner with financial or strategic resources, licensing existing technology, or forming strategic joint ventures.

ATTRACTING EXTERNAL CAPITAL

The relatively low level of strategic activity, noted earlier, has minimized the influx of capital from the likes of private equity and institutional investors. This is not for lack of interest in the world of professional investors — quite the contrary. We constantly have conversations with investors who are very interested in putting money to work in this space, given its technology-rich nature and attractive industry growth rates. However, the size or stage of technology development in most companies simply falls outside of their investment criteria. This is unfortunate because institutional investors can add a lot of value to a company by giving it the resources to grow exponentially while they create a lot of equity value for shareholders along the way. To put things in perspective, in most private-equity transactions, the original owners and management team retain 20 to 50 percent ownership and operational control in the business. Therefore, the economic value created through institutional ownership typically far exceeds the initial purchase price in a transaction. So for business owners who are thinking about their companies' long-term growth, critical areas of strategic focus include exit or succession plans, growth scale and enterprise value.

OUTLOOK FOR 2013

For company owners who are considering an exit strategy or selling their business, 2013 looks to be ideal. Valuation levels remain strong for businesses that are performing well, and we saw some very attractive *valuation multiples* paid in M&A transactions last year. For example, Cytec's acquisition of Umeco represented a multiple of 10 *times* EBITDA (earnings before interest, taxes, depreciation and amortization). Although a 10x multiple shouldn't be viewed as the norm, it is not unreasonable to think that well-run businesses with definitive strategic differentiation will trade near this range. Generally, we are seeing acquisition


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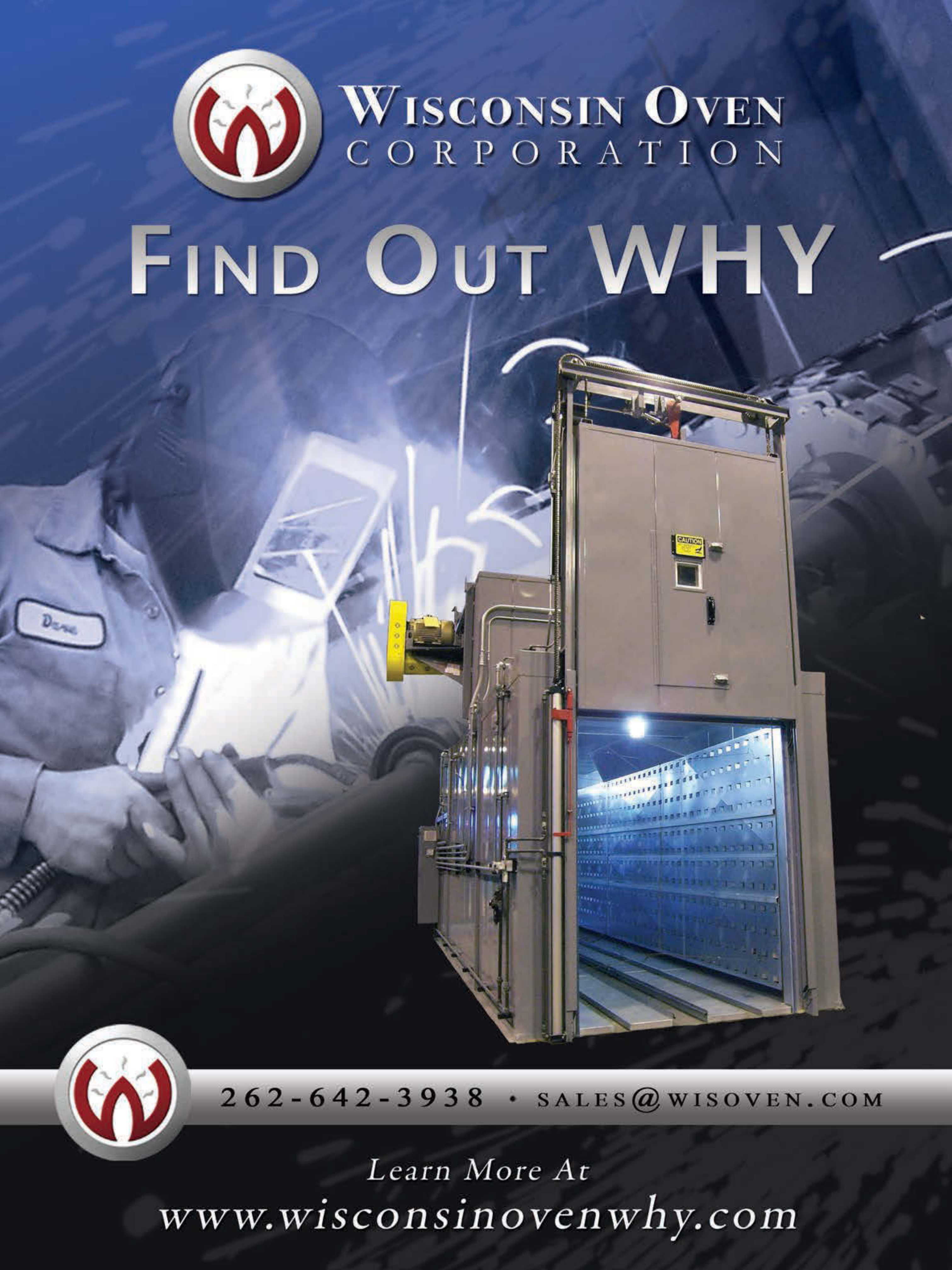
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multiples return to prerecession levels regardless of industry. This is a good sign.

Beyond valuation metrics, 2013 should be a strong year for business owners who are looking to make an exit in the next few years. Given the transition to production on major aerospace platforms, the market is generally at a healthy point in the cycle. But in any industrial sector, the cycle can change quickly. Strong market conditions don't turn on a dime, but they also don't last forever. At some point, there will be another downturn, and it's not out of the question that it could come in the next couple of years. Larger companies with owners near their golden years will face a decision: either invest in innovation or make acquisitions to spur growth and stay competitive. We don't expect owners who survived the last downturn to have an appetite for going through another one. We will not be surprised to see, before too long, some of the more well-known names in the industry change hands.

The author extends a special thanks to industry consultant Steve Speak (Steve Speak Coaching and Consulting, Scottsdale, Ariz., steve@stevespeak.com) for his contribution to this article. ■

TESTING TECH

FLEXURAL TESTING 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*.

Flexural strength and stiffness are *not* basic material properties. They are the *combined effects* of a material's basic tensile, compressive and shear properties. That is, when a flexural loading is applied to a specimen, *all three* of the material's basic stress states are induced. Material failure, then, is dictated by which of the three basic stresses is the first to reach its limiting value — that is, its strength. Despite the obvious complexities implied by the above, flexural *testing* is common, the test specimen is easy to prepare, the fixture can be simple and the test itself is easy to perform.

To simplify the stress state in the specimen, it is customary to minimize the shear stress component. This is done by making the specimen support span (ℓ) long relative to the specimen thickness (t), because shear stress is independent of specimen length while the bending moment (and thus the tensile and compressive stress) is directly proportional to specimen length. Today, ℓ/t ratios of 16:1 and 32:1 are commonly used, but ratios of 40:1 and even 64:1 are sometimes specified. At any of these ratios, it is highly unlikely that the specimen will fail in shear.

Normally, the specimen is loaded while in a horizontal position, and in such a way that the compressive stress occurs in the upper portion and the tensile stress occurs in the lower portion of the cross section. If the specimen is symmetrical about the midplane of its cross section (e.g., rectangular), the maximum tensile and compressive stresses will be equal. Thus, whether the specimen fails in tension or compression simply depends on which strength value is lower. For most, but not all, composites, the compressive strength is lower, and thus the specimen will fail at the compression surface. Typically, this compressive failure is associated with the local buckling (microbuckling) of individual fibers.

Both three-point and four-point loading configurations are used. Three-point loading consists of a support point near each end of the beam and one load point at the midspan. For four-point loading, there are two load points at equal distances from the support points. This distance is typically one-fourth of the span length (thus, the term quarter-point four-point loading), but a distance of one-third of the span length (third-point four-point loading) is sometimes used. Relatively little difference in test results has been demonstrated between three-point and four-point loading, so the choice between the two typically is one of personal preference.

Because it is usually desirable to test at a specific ℓ/t ratio, a general-purpose flexure test fixture has to have adjustable support and loading spans to accommodate specimens of various thick-

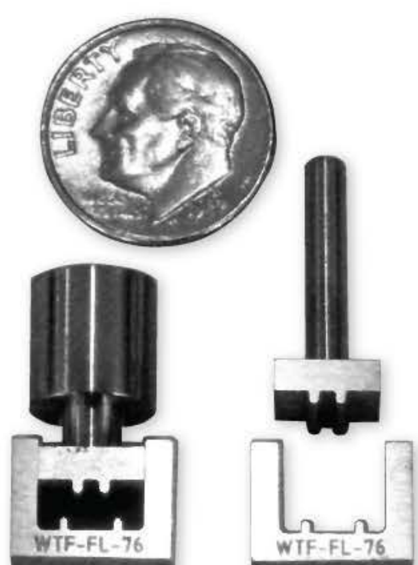


Fig. 1 A miniature four-point loading test fixture with radiused supports.

Fig. 2 A flexure fixture with loading/support cylinders supported in V-grooves.

Fig. 3 An example of a rolling support.

All photos courtesy of Don Adams.

nesses. A *fixed-span* fixture (see example in Fig. 1) is thus limited to specimens of a specific thickness if a specific ℓ/t ratio is to be adhered to. Note that the fixture in Fig. 1 has radiused supports and loading points. When the specimen is loaded, the bottom surface is in tension, and thus becomes longer, causing the specimen to slide on the two supports. The frictional forces generated at the bottom surface are directed toward the midspan, so as the specimen deflects downward these frictional forces add to the bending of the specimen. This typically has a small effect, but can be of concern, as can the wear on the test fixture when the specimen slides. Thus, test fixtures that have radiused supports, such as the fixture in Fig. 1, typically see special or limited use.

The common alternative to a fixture with radiused supports is to support a cylinder in a V-groove. Although friction between the cylinder and the V-groove usually prevents the cylinder from rotating as the specimen is loaded, the cylinder can be made of much harder material than the remainder of the test fixture to resist wear. Also, if the cylinder is not permanently attached but instead held in place by springs or other removable restraints, the cylinder can be rotated to a fresh contact surface if it shows signs of wear. Fig. 2 shows a fixture with removable cylinders. An added benefit is that cylinders of other diameters can be used, although this is limited by the size of the V-groove. Although one can mount the cylinder ends in ball or roller bearings, the latter tend to be bulky and have limited load capacity, so they also find only special use.

A more practical approach is to use rolling supports (Fig. 3). These roll outward as the specimen deflects and the loading rollers roll inward. Although this changes the loading and support span lengths slightly, the change is typically small and, thus, usually ignored. The rolling supports eliminate sliding friction and reduce wear. And if the initial position of the roller is dictated by indexing an axle of fixed diameter against a stop (as in Fig. 3) rather than indexing the roller itself against the stop, an important secondary advantage is that rollers of a relatively large range of diameters can be used with the same fixture, without affecting the support (and loading) span scales that are typically engraved on the test fixture. Perhaps greater use will be made of rolling supports in the future.

Typically, all three or four loading/support points lie in the same horizontal plane. Thus, if the specimen has any twist along its length, or has top and bottom surfaces that are otherwise not flat and parallel to each other, it will not rest uniformly on the contact surfaces. For flexible materials, this is not a significant problem because as soon as the load is applied, the specimen readily conforms to the supports, and in doing so, induces minimal extraneous stresses. For rigid materials, however, this might not be true. In such cases, articulated test fixtures are used. All but one of the support/loading cylinders is free to pivot in the vertical plane across the width of the specimen, thus conforming to the slope of the specimen at that location.

Given this variety of flexural test configurations, it is unfortunate that more logical selections for their use have not been made over the years. There has been regrettably little coordination between the various flexural test standards. Next time, I will survey the standards and suggest how they could be unified. ■

NEWS

Boeing takes steps to bump up 787 build rate with building buy in Utah

Battery woes not expected to impact 2013 plane production schedule

The Boeing Co. (Chicago, Ill.) on Jan. 11 announced the purchase of an 850,000-ft²/78,976m² building in West Jordan, Utah. The facility eventually will house fabrication operations for composite horizontal stabilizer components destined for the 787-9 version of the company's *Dreamliner* aircraft. The new site is located only 20 miles from, and will complement, Boeing's existing fabrication and assembly site in Salt Lake City. The close proximity of the two facilities is expected to improve efficiency as stabilizer components move from fabrication to assembly stages.

"The site we've chosen is an ideal location to add composite manufacturing capability focused on Boeing's key business strategies," says Ross R. Bogue, VP and general manager of Boeing Fabrication. "This new facility will provide a real competitive advantage in our supply chain by expanding our internal composite capabilities."

Boeing has retained the services of Tacoma, Wash.-based Sitts & Hill Engineers Inc. to design the factory space. M. Torres Disenos Industriales SA (MTorres, Pamplona, Spain) will supply automated contour tape laying machines (CTLMs). Although design and construction activities are expected to continue for two years, Boeing Salt Lake director Craig Trewet says, "Hiring will begin immediately. We'll begin by hiring project managers and engineers and will then be filling production positions over the next several quarters."

The move came at a time when Boeing faced temporary grounding of all 787 *Dreamliner* aircraft by the U.S. Federal Aviation Admin. (FAA) while an investigation proceeds into two fires involving the craft's lithium-ion battery packs. On Jan. 16, Boeing chairman, president and CEO Jim McNerney issued the following statement, after the FAA issued an emergency airworthiness directive (AD) that requires U.S. 787 operators to temporarily cease operations and recommends that other regulatory agencies follow suit: "The safety of passengers and crew members who fly aboard Boeing airplanes is our highest priority. Boeing is committed to supporting the FAA and finding answers as quickly as possible. The company is working around the clock with its customers and the various regulatory and investigative authorities. We will make available the entire resources of The Boeing Co. to assist."

McNerney added that the company is confident the 787 is safe and that Boeing stands behind its overall integrity: "We will be taking every necessary step in the coming days to assure our customers and the traveling public of the 787's safety and to return the airplanes to service. Boeing deeply regrets the impact that recent events have had on the operating schedules of our customers and the inconvenience to them and their passengers." He affirmed on Jan. 30 that, the grounding notwithstanding, 787 production would proceed apace, with Boeing still on track to produce 60 planes this year.

This is not the first time the safety of lithium-based batteries in aircraft has been called into question — reportedly, there have been more than 20 previous incidents. On Oct. 7, 2011, for example, the FAA issued an emergency AD for Cessna 525 (*Citation* jet) airplanes, prompted by a report of a battery fire that resulted after an energized ground power unit was connected to one of the affected airplanes equipped with a lithium-ion main aircraft battery. This condition could result in an aircraft fire, said the FAA at that time. The solution in the Cessna case was to replace lithium-ion main aircraft batteries with NiCad or lead-acid batteries, a solution that would add significant weight to the fuel-efficient *Dreamliner*. On Jan. 25 the *Seattle Times* revealed that during lithium-ion battery testing in 2006 at a Boeing supplier involved in the 787's battery system, a battery exploded and burned the supplier's main buildings to the ground.

Source: Boeing

Web Industries acquires CAD Cut

Custom flexible materials manufacturer Web Industries Inc. (Marlborough, Mass.) announced on Jan. 10 the acquisition of CAD Cut Inc. (Middlesex, Vt.), a provider of fabric cutting and kitting services for the aerospace, medical and industrial-fabrics markets. Under the terms of the transaction, Web purchased essentially all of the assets of CAD Cut, including the company name. Web Industries says it will continue to operate CAD Cut's existing manufacturing facilities, which are located at its headquarters in Middlesex and in Denton, Texas. (*Continued on p.* 17)

(*Continued from p. 17*)

CAD Cut specializes in providing composite ply kits to the aerospace, aviation, defense and industrial markets. The company also manufactures multilayer insulation blankets for cryogenic applications in medical devices and produces process aids used in conjunction with wind-tunnel testing devices.

Web Industries is a privately held, 100 percent employee stock ownership plan (ESOP) company. Its mission is to provide commercial-scale outsource converting, manufacturing and development services to a wide array of customers in the aerospace composites, consumer products, medical and wire/cable markets.

The acquisition is expected to exploit synergies between the two companies, especially in the aerospace sector, where Web Industries has provided precision composite slit tape for automated manufacturing and CAD Cut has supplied precut and kitted material for hand layup of advanced composite parts. With the addition of CAD Cut's ply cutting and kitting capabilities to Web Industries' proprietary composite slitting, spooling, chopping and winding technologies, the combined company expects to be able to offer a full range of advanced composite formatting solutions.

"Web Industries is thrilled to add CAD Cut's ply cutting and kitting services to our own PrecisionSlit converting technologies in order to offer the composites, medical, and industrial fabrics markets an even more comprehensive suite of material formatting services and solutions," says Donald Romine, president and CEO of Web Industries. "We were attracted to CAD Cut because they're the best at what they do, and what they do is a natural extension of what we're best at doing."

Commenting on the acquisition, CAD Cut's president, Ward Osgood, says, "I'm extremely pleased by the advantages brought to our customers and employees through the combination of these two organizations. The financial and operational strength that Web brings, coupled with their deep expertise in CAD Cut's markets, will provide substantial benefits to our customers through expanded and improved services."


Source: Terrafugia

"Roadable aircraft" update: Terrafugia *Transition* in flight/drive testing phase

Conceived by MIT-trained engineers in 2006 and built with composites, the Terrafugia (Woburn, Mass.) *Transition* flying car continues its journey toward certification and commercial launch. The company announced in January a cash infusion ($2.7 million from a Series D1 investment round) and successfully completed its contribution to Phase II of the DARPA Transformer (TX) program with the delivery of three-quarter scale hardware and test data. DARPA TX is a five-year, three-phase flying-car project coordinated by the Defense Advanced Research Projects Agency (DARPA) for the U.S. military. Concurrently, Terrafugia COO Anna Mracek Dietrich has been active as an industry representative on the U.S. Federal Aviation Admin. (FAA) Aviation Rulemaking Committee (ARC), which is doing analysis and providing recommendations for a revamp of *Federal Aviation Regulations* (*FAR*) Part 23. Dietrich's participation reportedly has given the company tremendous insight into the evolution of the light-aircraft certification process.

CEO and chief technology officer Carl Dietrich reports that flight and drive testing is underway to evaluate the durability of the *Transition* airframe in a real-world environment. Necessary modifications are being made on the current prototype. "Once the engineering team is satisfied that the majority of the field issues have been identified from this prototype," he notes, "we will evaluate if the number and magnitude of potential modifications warrant the construction of another prototype prior to final compliance testing for certification."

Although engineers are pleased with the *Transition's* flying and driving characteristics, the company says recent flight testing resulted in some aerodynamic improvements. The most substantial was an extension of the leading-edge strake at the root of the wing to reduce the magnitude of wing/fuselage interference drag. A secondary benefit of this modification is stiffening of the doors.

The *Transition* must meet the Federal Motor Vehicle Safety Standards (FMVSS) of the National Highway Traffic Safety Admin. (NHTSA) as part of the automotive certification process. Drive testing recently moved from the corporate parking lot to the New Hampshire Motor Speedway.

Says Carl Dietrich, "The Terrafugia team is committed to delivering the best possible street-legal airplane to our loyal customers."

BIZ BRIEFS

Hexcel Corp. (Stamford, Conn.) announced on Jan. 22 that it had received a 2012 Boeing Performance Excellence Award. The Boeing Co. (Chicago, Ill.) issues the award annually to recognize suppliers who have achieved superior performance. Hexcel maintained a Silver composite performance rating for each month of the 12-month performance period, from Oct. 1, 2011, to Sept. 30, 2012. "We are proud to be recognized by our largest customer for superior supply performance," said Mike Canario, Hexcel VP and general manager for the Americas.

According to a story at the Naval-Technology.com Web site, dated Jan. 3, and several other publications, the U.S. Navy has awarded a modification contract to the **Bell-Boeing Joint Program** (Amarillo, Texas) to develop and deliver 21 additional V-22 *Osprey* aircraft. Under the $1.4 billion modification deal, which follows a previously awarded contract, Bell-Boeing will supply 17 MV-22 *Osprey* aircraft to the U.S. Marine Corps (USMC) and four CV-22 aircraft to U.S. Air Force (USAF) Special Operations. Under the contract terms, the partnership also will provide the long-lead components necessary to develop and deliver 19 MV-22 tilt-rotor aircraft to the USMC and 18 CV-22 tilt-rotor aircraft to the USAF in fiscal year 2014, says the published report. The composites-intensive aircraft has been designed to support a wide range of naval missions, including combat, search and rescue, fleet logistics support, special warfare support and amphibious assault, as well as long-range "special ops" infiltration and exfiltration. Work on this contract is scheduled to be complete in September 2016, with the U.S. Naval Air Systems Command serving as the contracting entity.

TenCate expands reach and offerings with Amber Composites acquisition

Thermoplastic composites giant TenCate (Nijverdal, The Netherlands) reported on Jan. 16 that it has reached an agreement in its quest to acquire Amber Composites (Langley Mill, Nottingham, U.K.), a manufacturer of thermoset composites for the industrial and automotive markets. The deal is expected to accelerate TenCate's European market activities in the thermoset composite materials field.

TenCate developed thermoplastic composites for the aviation industry 20 years ago, under the brand name TenCate Cetex. The company says this acquisition will help increase its U.S. and European presence in industrial and automotive composites, tooling materials and aerospace applications with a stronger and more balanced product portfolio that features both thermoplastic and thermoset composites.

The move followed TenCate's recently announced alliance with BASF AG (Ludwigshafen, Germany) to develop, manufacture and commercialize thermoplastic composites suitable for high-volume automotive production, and the company's agreement with 3M (St. Paul, Minn.), aimed at increasing TenCate's presence in the U.S. tooling market. Tooling composites is a reported area of strength for Amber Composites. The recent acquisitions of PMC Baycomp (Burlington, Ontario, Canada) in North America and, now, Amber Composites support the company's expansion plans in this market.

CLARIFICATION

In the November 2012 issue of *HPC*, we reported on the use of carbon fiber in the manufacture of carbon fiber musical instruments, including violins, cellos and guitars. The article included a review of the history of carbon fiber in instruments. Unfortunately, we overlooked one major contributor.

Leonard K. John, senior engineering advisor, materials technology, at Bombardier (Toronto, Ontario, Canada), reports that he developed the world's first carbon fiber violin in the 1970s, and in 1983 he was granted the first U.S. patent for a carbon fiber violin and related instruments, including the viola, cello and bass. John tells *HPC* that he has produced nine violins to date, with a 10th under consideration.

John's original carbon fiber violin is on display at the Ontario Science Center in Toronto. His instrument also is on display at the National Music Museum at the University of South Dakota (Vermillion, N.D.). To read more about the violin, visit http://orgs.usd.edu/nmm/News/Newsletter/August2010/StyronRevolution.html#10667.

HPC regrets that John's work was not noted and credited in the original report.

BIZ BRIEF

Gougeon Brothers Inc. (Bay City, Mich.) has announced an overhaul in the chemistry, pricing and marketing of its PRO-SET line of advanced composite epoxies. The company chose to revamp the line after noting a unique trend: PRO-SET custom resin formulations were consistently outselling some of the epoxies in its standard PRO-SET product line. The company says it realized it could deliver these popular custom products to customers faster, and at more competitive prices, by making them part of its standard product line. Accordingly, Gougeon's chemists reformulated the PRO-SET line for enhanced performance and adjusted the chemistry to allow 3:1 mix ratios across the board in the laminating and infusion epoxies. PRO-SET resins can now be chosen by viscosity, and hardeners can be chosen by speed. This allows engineers and fabricators to select a resin/hardener combination that best suits their specific projects and processes. PRO-SET hardeners are now priced the same in each category, regardless of cure speed. Gougeon also reorganized PRO-SET's product offerings into four distinct categories: Laminating, Infusion, Tooling and Adhesives. All products have been given a category prefix of LAM, INF, TLG or ADV to assure the compatibility of resin and hardener selections.

BIZ BRIEF

To commemorate the organization's 40th anniversary, **Airtech Advanced Materials Group** (Huntington Beach, Calif.) has created a custom logo that will be featured throughout 2013 and has launched a new Web site. The anniversary celebration, first announced on Nov. 16 last year, will continue all year long at all Airtech-related locations worldwide. The anniversary logo prominently features the number 40 to commemorate the four decades the company has been in business. The new Web site, says the company, will be a "hub" that links to Web sites operated by each of Airtech's individual facilities. It is designed to be easy to navigate and can stream demonstration videos with a simple click of a button. Airtech was founded in 1973 by William "Bill" Dahlgren, an engineer who started the business with four people in San Bernardino, Calif. The goal was to create a "one-stop shop" and manufacture vacuum bagging and composite tooling materials for manufacturers of fiberglass and carbon fiber parts. Dahlgren is still active in the business and has seen his company grow to more than 500 employees, with worldwide manufacturing in Huntington Beach; Chino, Calif.; Differdange, Luxembourg; Rochdale, England, U.K.; and Tianjin, China. Airtech is privately owned and is an ISO 9001:2008 and an AS9100 Rev C-certified company.

BIZ BRIEF

The Magnolia Plastics Inc. (Chamblee, Ga.) board of directors has changed the company's name to **Magnolia Advanced Materials Inc.** The custom formulator of high-performance epoxy resin systems announced the impending change on Oct. 5, 2012. CEO Rick Wells notes that the decision reinforces the company's real-world activities and plans: "Our new name better reflects our current business and will grow with us as we add new chemistries and product lines. My father, Don Wells, founded the company in 1957 and began by developing epoxy for the aviation industry and emerging U.S. space program. Our tagline then was 'Plastics for the Space Age.'" Since those early days, Magnolia's products have flown on shuttle missions and into deep space on *Pioneer* and *Voyager* missions. Wells says his father "would be thrilled to see how we've grown, and that we still specialize in aviation of all types. I think he would be particularly proud that we are considered a leader in another emerging space industry: space tourism. Our name has changed but our commitment to excellence in customer service and innovative product development will remain our primary focus." Magnolia Advanced Materials Inc. is AS9100-certified.

University of Maryland team hovers near Sikorsky Prize


Source: University of Maryland

In 1980, the American Helicopter Society (Alexandria, Va.) announced the Igor I. Sikorsky Human Powered Helicopter Competition to encourage just that, development of the world's first human-powered rotorcraft. In the years since, no one has yet fulfilled the competition's requirements: controlled flight of at least 60 seconds, reaching an altitude of 3m/9.8 ft and remaining within a 10m/32.8 ft square. But in 2012 a team from the University of Maryland showed signs that the day is near.

On June 21, 2012, in the Reckord Armory on the campus of the University of Maryland in College Park, the university's *Gamera* team flew its *Gamera* II rotorcraft. Piloted by mechanical engineering doctoral candidate Kyle Gluesenkamp, the craft set a new official U.S. record for human-powered rotorcraft flight duration at 49.9 seconds. A refined version of its earlier *Gamera* I vehicle, designed and built by students in the Clark School of Engineering, *Gamera* II is 30 percent lighter than the original and is designed for flights of more than 60 seconds — much longer than the 11.4-second world record set by *Gamera* I and enough to meet the Sikorsky Prize requirement. *Gamera* II features enhanced rotor design, an improved transmission and a redesigned cockpit. The June 21 flight was verified by the National Aeronautic Assn. (Washington, D.C.) on Aug. 9, 2012, and has been submitted to the Fédération Aéronautique Internationale (Lausanne, Switzerland) for world-record review.

Gamera II features four substantial rotors at the ends of an X-shaped frame made of carbon fiber trusses. The configuration increases vehicle stability yet puts the rotors as close to the ground as possible, increasing *ground effect*, a "free" increase in lift experienced by wings and rotor blades operating near the ground. The team spent more than a year designing and building a ground-effect test rig and developing empirical models to optimize *Gamera* II's rotor design to exploit ground effect. The trusses are a novel concept, with a truss-of-trusses design wherein the most critically loaded members in the airframe truss have been replaced with "micro trusses" that provide unmatched buckling resistance with significant weight savings, says the team.

In August and September the team flew a further refined version of *Gamera* II. One flight surpassed the Sikorsky competition's duration requirement, at 65 seconds, and stayed within a 10m/32.8 ft square area, but it did not reach the required altitude. That flight is under review for world-record consideration. Subsequent flights of shorter duration came close to the height requirement; one flight reached 8 ft/2.44m and the other was just short, at 9.4 ft/2.87m.

Although modifications increased its weight by about 6 lb/2.72 kg, the refined airframe's rotor blades are longer by 700 mm/27.56 inches (with structural arms longer by 1m/3.28 ft). The blades and outboard sections are now made of semisolid foam shell to help maintain airfoil shape during flight. Further, the cockpit now allows more pilot arm flexion to increase the available power. The powertrain has a stiffer chain and modified tensioners that smooth power transfer.

BIZ BRIEF

M1 Composites Technology Inc. (Laval, Quebec, Canada) has opened its new advanced composites repair facility and manufacturing plant. The state-of-the-art

Source: M1 Composites

operation is designed to provide rapid turnaround of damaged commercial and military aircraft components. "Our team of highly experienced technicians combined with a cutting-edge facility will provide a catered solution to meet specific customer needs," says Lorenzo Marandola, M1 Composites president. "The key factor in achieving a rapid turnaround for repairs is the proximity to the Montreal airport and military maintenance operations, coupled with the internal agility of the M1 system." The 24,000-ft²/2,230m² facility features a certified cleanroom, a large curing oven, a paint finishing operation and a full complement of repair equipment. As a new entity in the aircraft composites repair arena, M1 Composites has been positioned to provide top-level resources and highly qualified personnel to serve the aircraft, military and commercial markets. For more information about the company, visit its Web site: www.m1composites.com.

Airbus A350 XWB's Rolls-Royce turbofan awarded type certification

Airbus (Toulouse, France) reported on Feb. 7 that its composites-intensive A350 XWB airliner has achieved another important program milestone in its progress toward aircraft type certification and full-rate production. The European Aviation Safety Agency (EASA, Koeln, Germany) awarded Engine Type Certification to the A350 XWB's Rolls-Royce (London, U.K.) Trent XWB turbofan jet engine.

The certification covers Trent XWB engines that will power the A350-800 and A350-900 aircraft. A newer version of the Trent XWB, which will be capable of greater thrust, is currently under development for the larger A350-1000 variant.

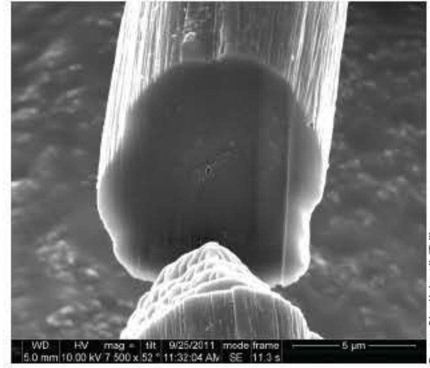
Certification confirms that the engine has fulfilled EASA's airworthiness requirements and is the last major engine milestone prior to the first flight of A350-900 MSN001, scheduled for later this year. The engines that will power that aircraft are being prepped for installation.

Since February 2012, the Trent XWB has been trialed on Airbus' A380 Flying Test Bed (FTB) aircraft. FTB test results indicate that the engine will meet the A350 XWB program's efficiency and performance goals. Airbus' executive VP Didier Evrard claims, "These new engines together with the aircraft's advanced aerodynamics and airframe technologies will bring our airline customers a 25 percent step-improvement in fuel efficiency."

"Superfiber" created in nanospinning process

Researchers at Teijin Aramid BV (Arnhem, The Netherlands) and Rice University (Houston, Texas) announced the publication of their research findings on a new generation of "superfibers" in the scientific journal *Science*. In a Jan. 11 announcement, the researchers declared that, for the first time in history, it is possible to spin carbon nanotubes (CNTs) into a fiber that is as thin as a strand of DNA yet, according to Teijin Aramid's business development manager, Marcin Otto, combines "high thermal and electrical conductivity, like that seen in metals, with the flexibility, robust handling and strength of textile fibers." Otto adds, "With that novel combination of properties, it is possible to use CNT fibers in many applications in the aerospace, automotive, medical and smart-clothing industries."

For several years, researchers at Rice University, including Nobel prize winner Richard Smalley, and Teijin Aramid have been working on producing CNTs and forming them into useful macroscopic objects with extraordinary new performance properties. To spin a high-performance carbon nanotube textile thread or fiber, the nanotubes must be perfectly stacked and oriented along the fiber axis. According to the company, the most efficient method for doing this is to dissolve the CNTs in a superacid, followed by wet spinning — the same patented process that has been used since the 1970s to spin Teijin Aramid's Twaron para-aramid fiber.



Source: Rice University/Teijin

Teijin says the Twaron technology enabled improved performance and is an industry-scalable method for manufacturing the nano superfiber. The method is expected to make it possible to apply CNT fibers in a wide range of commercial and industrial products.

"This research and ongoing tests offer us a glimpse into the future possibilities of this new fiber," says Otto. "For example, we have been very excited by the interest of innovative medical doctors and scientists exploring the possibilities to use CNT fiber in surgical operations and other applications in the medical field." Teijin Aramid expects the fiber to replace copper in data cables and light power cables used in the aerospace and automotive industries, making aircraft and cars lighter yet more robust.

Other applications could include integrating lightweight electronic components, such as antennae, into composites, or replacing cooling systems in electronics, where the high thermal conductivity of carbon nanofiber could dissipate heat. Teijin Aramid is trialing samples on a small scale with its most active prospective customers. Building a robust supply chain is high on the project team's priority list. Teijin Aramid's collaborators include research groups led by Professor Matteo Pasquali and Professor Jun Kono at Rice University, the Technion-Israel Institute of Technology (Haifa, Israel), and the U.S. Air Force Research Laboratory (Dayton, Ohio).

ADVERTISEMENT

NORTH RHINE-WESTPHALIA: AN INNOVATIVE LOCATION THANKS TO NEW MATERIALS

New materials form an important basis for innovative products and applications. North Rhine-Westphalia is already one of the leading locations for materials technology in Germany. As a result of the intensive cooperation between industry and research, the federal state possesses excellent credentials.

The performance, cost-effectiveness and resource efficiency of many industrial products depends to a large extent on the materials used. For example, innovations in the materials sector can conserve material and energy resources or reduce pollution. Their possible applications range from automotive engineering and optics through electronics, modern communications technologies and medical technology to architecture and the construction industry.

For North Rhine-Westphalia the field of new materials is one of the most important future industries. Today, 40 percent of the North Rhine-Westphalian gross domestic product is already generated with products and services based on innovative materials. With 6,110 companies and research facilities, 726,000 jobs and approx. 200 billion euros in sales, North Rhine-Westphalia is one of Germany's leading locations for new materials. Internationally renowned players such as 3M, Bayer, Evonik Industries, Henkel, Hydro Aluminium, Saertex and ThyssenKrupp develop and utilize new materials here. Many companies in this sector have their headquarters in the Ruhr Metropolis and the Rhineland in particular. For example, Bayer MaterialScience is working at Chempark Leverkusen on manufacturing high-grade plastics from the climate-damaging waste product carbon dioxide.

Besides large corporations with international operations, the industry in North Rhine-Westphalia is characterized by innovative SMEs (small and medium-sized enterprises). Zoz GmbH in Wenden, for example, is a world market leader in nanostructured materials. The ‚Zentallium' product developed here is as light as aluminum yet stronger than steel.

Success stories like these are possible only as a result of close cooperation between science and industry. North Rhine-Westphalia offers the densest research network in Europe and ideal conditions for technology transfer. More than 22 universities and non-university research institutes, including 120 specialized professorships, conduct research in North Rhine-Westphalia into the development of marketable products and processes in the field of new materials.

Muensterland – top location for materials in North Rhine-Westphalia

Situated in the north of North Rhine-Westphalia, Muensterland offers a broad spectrum of materials competences. The companies and research institutes based here are particularly innovative when it comes to the development of technical textiles, paints and varnishes. The international corporations BASF Coatings and Brillux, for example, are based here. Companies in the region are also world leaders in the production and application of composites and high-performance plastic and metal materials. How existing competences – such as the manufacture of textile surfaces – become future-oriented technologies through innovative materials is demonstrated by Saertex. The company makes extremely resilient industrial textiles out of fiberglass, carbon and aramid – so-called non-crimp fabrics (NCF). These extremely lightweight materials are processed individually as components for aircraft, wind turbines, bridges, ships and automobiles.

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Source: *HPC* / Photo: Jeff Sloan

JEC EUROPE 2013 & SAMPE EUROPE 2013 PREVIEW

WHAT:	**JEC Europe 2013**
WHEN:	**March 12-14, 2013**
WHERE:	**Paris Expo, Porte de Versailles, Paris, France**
WHAT:	**SAMPE Europe 2013 (SEICO 13)**
WHEN:	**March 11-12, 2013**
WHERE:	**Hotel Mercure, Porte de Versailles, Paris, France**

Record attendance expected at world's largest annual gathering of composites industry professionals.

Sold Out! That's the word from the JEC group as it prepares for its composites industry trade show in Paris. Slated for March 12-14 at the Paris Expo (Porte de Versailles, Paris, France), the JEC Europe Show is the annual meeting place for the world's top composite professionals. Show organizers say that, for the 2013 edition, they've filled every stand on its 50,000m² (538,195 ft²) show floor — an area equal to *eight* soccer fields. More than 1,100 exhibitors will be on hand, 80 percent of them from outside France. Europe will account for 74 percent of the exhibitors, while 10 percent will come from the U.S. and 13 percent from Asia's emerging markets.

JEC Europe exhibitors serve a wide range of end markets. Automotive and marine top the list, each served by 14 percent of the exhibitors; 13 percent serve the aerospace sector, 12 percent support building/construction; 11 percent, rail transit; and 10 percent, wind energy. About 31 percent of the exhibitors supply raw materials, 22 percent are equipment suppliers, and 39 percent offer processing or other services.

JEC organizers say the 2013 show will highlight 12 "key themes" during the three-day event: Design, Nondestructive Testing, Robotics, Aeronautics, Automotive, E-car, Wind Power, Carbon, Biocomposites, Thermoplastics, Multifunctional Materials and the Environment. "The sector, notably in Europe, has strongly advanced in the processing of composites. Especially in Europe, innovation is directed towards manufacturing, and in particular, mass production," says JEC's executive director Frédérique Mutel, putting special emphasis on the key area of robotics: "Of all the patents granted for composites in Europe in 2011-2012, 52 percent involved robotics and automated manufacturing processes. It is probable that these technological advances will primarily interest major international contractors and decision-makers in countries with rapidly growing populations and economies."

The world comes to Paris

JEC predicts more than 32,000 attendees in 2013, while SAMPE Europe plans a dual focus on aerospace and the developing automotive market.

Mirroring growth

JEC expects a record crowd in the aisles. Organizers predict more than 32,000 attendees, based on what JEC says is a cumulative 86 percent hike in the number of visitors in the past decade. The attendance numbers mirror JEC's survey findings on composites industry growth. The global composites market, according to JEC estimates, achieved a total value of €81.6 billion ($106.4 billion USD), delivering 9.2 million metric tonnes (20.28 billion lb) of product in 2012. Further, the composites industry is growing an average of 6 percent per year. "Composites are used more and more often to lighten structures, aircraft, and vehicles in general, thus improving energy efficiency," says Mutel. "Innovation is present in each of the steps of the value chain." Producers of raw materials (polymers, as well as carbon, glass and natural fibers) have heavily invested in the research and development of new formulations. "Downstream, at the part manufacturing level, the industry is also highly innovative."

The European segment of the 2013 JEC Innovations Awards Competition will culminate in Paris with show-floor displays of products designed and built by award winners and runners up.

JEC's "Country of Honor" this year is Turkey, in recognition of its composites presence in the automotive and pipe/tank manufacturing markets. According to JEC figures, Turkey's composites manufacturers produce about 200,000 metric tonnes (440.9 million lb) of composite product per year, valued at €1 billion ($1.3 billion USD).

SAMPE Europe 2013

A short distance from the Paris Expo, the European arm of the Society for the Advancement of Material and Process Engineering (SAMPE Europe) will present its 34th International Conference. The two-day event will feature two keynote addresses. The first, geared to SAMPE's foundational aerospace market, will be given by copresenters Nicholas Melillo and Andrew Mallow from The Boeing Co. (Chicago, Ill.) on the subject of "Rapid Prototyping as a Tool for Technology Insertion." The other, on day two, will feature a focus on the up-and-coming automotive market. Dr. Armin Plath, Volkswagen AG (Wolsburg, Germany) will discuss his paper titled "From Small Scale to Volume Production — How to Make Carbon Fiber Mainstream."

Overall, the conference has attracted, in addition to the keynote presentations, 55 technical papers. Aerospace papers are plentiful enough that the sector will have its own, dedicated plenary session on day one. Likewise, on day two, one session will focus only on automotive.

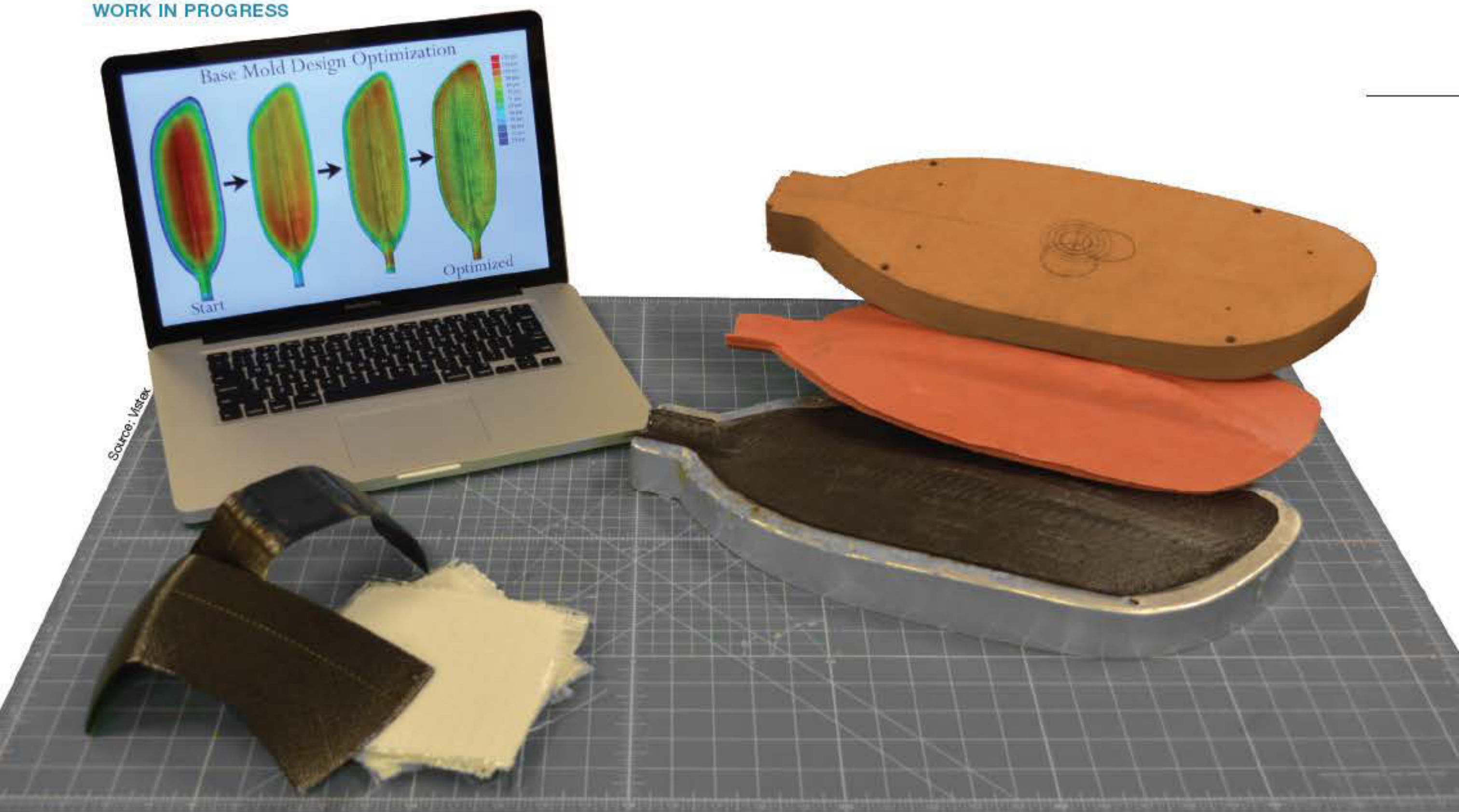
Early arrivers can take in the Welcome Reception on March 10, in the Hotel Mercure Atrium (finger food and drinks from 6:30 to 8:00 p.m.). The event sessions are fully catered on both days, and on March 11, the annual conference dinner will commence at 7:30 p.m. On March 12, SAMPE Europe will provide complimentary shuttle bus service, four times each hour, to and from the Expo gate. Further, conference attendees will receive a free CD of the conference proceedings. Additional copies of the CD may be purchased for €70.00 (approx. $91.00 USD).

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@jeccomposites.com; Web site: www.jeccomposites.com.

For more information about SAMPE Europe 2013 (SEICO 13), E-mail: sebo@sampe-europe.org; Web site: www.sampe-europe.org.

CW LEARN MORE @ www.compositesworld.com

See expanded show coverage, including a map of the JEC Europe 2013 show floor and a list of exhibitors and their stand locations, at http://short.compositesworld.com/RV5cZc2o.



PRESS-MOLDING METHOD EMULATES AUTOCLAVE

BY SARA BLACK

Rubber tool insert avoids consolidation pressure "dead zones" *and* slashs cost.

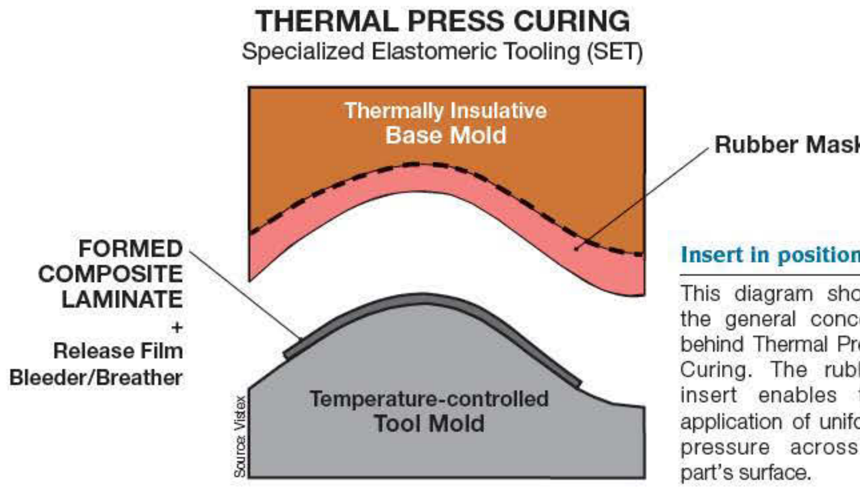
As the composites industry looks for ways to simplify and accelerate part processing, finding alternatives to autoclave cure has been a recurring theme. The Holy Grail? An alternative that offers the benefits of an autoclave *without* the high capital and energy costs. Vistex Composites (Howes Cave, N.Y.) may have found one in its (pat. pend.) Thermal Press Curing (TPC) technology. Marketed under the trade name Specialized Elastomeric Tooling, the method reportedly offers game-changing reductions in processing cost, complexity and energy consumption, as well as short tooling lead times for thermoset *and* thermoplastic prepreg parts.

Dr. Jaron Kuppers, chief technology officer at the startup company, a spinoff from the Rensselaer Polytechnic Institute's Center for Automation Technologies and Systems (CATS, Troy, N.Y.), says that Vistek's focus was a method that could apply an autoclave's uniform temperature and consolidation pressure to parts both faster and cheaper. What the company ultimately developed is similar to the metal world's Guerin process, sometimes called rubber pad forming, in which sheet metal is pressed between a forming die and a block of rubber. In TPC a composite prepreg layup is placed on a heated and temperature-controlled metal "curing mold." A matching "base mold" is created and fitted with a thin, cast-in-place silicone rubber face, what Vistex calls a "mask," in the approximate shape of the part. The layup is processed by enclosing the two molds in a press and applying pressure roughly equal to that applied by the autoclave, which has a functional limit, according to Kuppers, of about 125 psi/8.62 bar. The rubber mask aids in consolidation and, most importantly, equalizes the applied pressure across the part surface while the tool mold heats and cures the part.

"The uniform pressure across the part surface effectively reproduces the consolidation pressure provided by an autoclave," asserts Kuppers. "The key is designing the mask for uniform pressure." Although the pressure on the vacuum bag during autoclave curing is uniform, he explains, "this doesn't necessarily mean that the pressure on the part is uniform. In some situations, such as when a bag is trying to bridge a really sharp corner, the bagging material gets stuck, then external pressure is not transmitted to the part." In fact, a void results that is filled by excess resin. The rubber mask and base mold is designed, says Kuppers, to

Autoclave alternative

The Thermal Press Curing (TPC) method, developed by Vistex Composites (Howes Cave, N.Y.): A heated aluminum curing mold, a production kayak paddle, a rubber insert and an unheated base mold machined from epoxy tooling board are stacked on the right side of the photo. The computer shows screen shots produced by the company's proprietary shape-optimization modeling techniques, which optimize the rubber mask insert for uniform pressure across the part. At lower left are examples of other benchmark parts.



Insert in position

This diagram shows the general concept behind Thermal Press Curing. The rubber insert enables the application of uniform pressure across a part's surface.

come into full physical contact with and apply even pressure to the part to avoid these potential pressure "dead zones."

Modeling for multi-element tooling

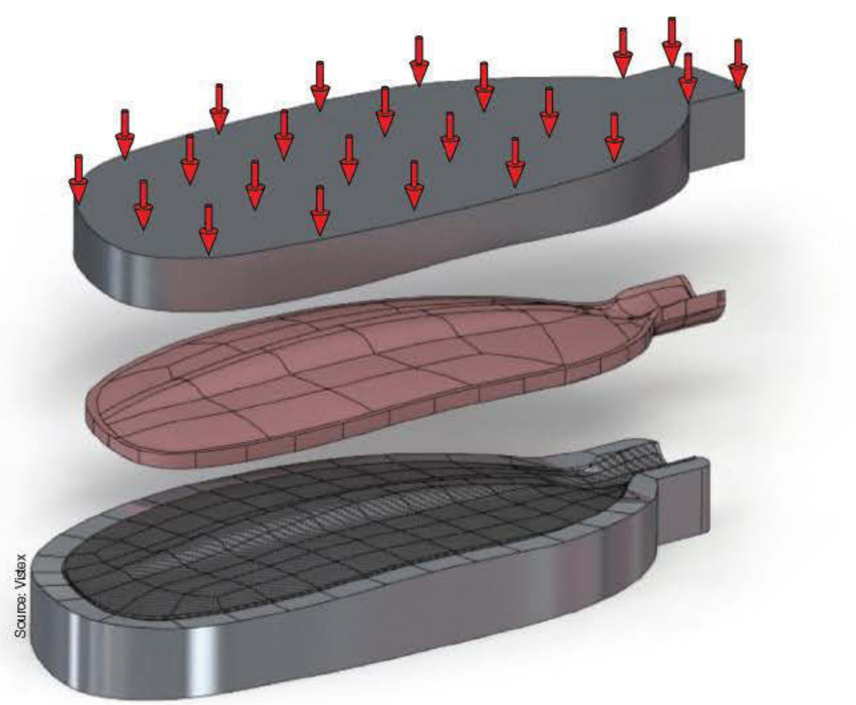
For an initial demonstration project that involved a benchmark industrial part, Vistex designed the molds using a SolidWorks computer-aided design (CAD) package from Dassault Systèmes (Waltham, Mass., and Vélizy, France). The curing mold was CNC-machined from solid billet aluminum. Its back side was configured to accept a 300W silicone membrane heater with etched foil elements, held in place by a thin aluminum cover plate, explains Kuppers. (A second, hollow aluminum mold was constructed from the same data, and outfitted with a membrane heater, for the comparative study described later.) To make the matching base mold, a second CAD model was created, assuming an initial uniform rubber mask with a thickness of approximately 0.5 inch/1.3 cm. Then, using COSMOS finite element analysis (FEA) software, also from Dassault Systèmes, this second model was used to simulate the mold set in compression and yielded the normal pressure distribution on the surface of the curing mold.

Pressure data from the model was analyzed within MATLAB from MathWorks (Natick, Mass.), using Vistex's proprietary shape optimization techniques. The MATLAB code generated revised mold and mask geometries and mask thicknesses that were imported back into SolidWorks, notes Dr. Daniel Walczyk, professor of mechanical engineering at CATS. This procedure was part of an iterative process that optimized the rubber mask to ensure that pressure would be essentially equal across the mold face.

Although the initial simulation showed that the surface pressure on the curing mold deviated, from minimum to maximum, by as much as 34 percent, the iterative process reduced the variation significantly to 13 percent. Additional modifications included extending the rubber insert beyond the part edges to ensure no abrupt drop-off in pressure.

"To compress the prepreg layup evenly, especially in a shaped, 3-D part, the rubber mask has to vary in thickness," says Kuppers, noting, "In general, the rubber layer will be thicker where the part layup is thicker, to ensure consolidation, and thinner at the edges, but the final shape is determined by the part shape, through the modeling."

For the demonstration, the base mold was CNC-machined from a block of laminated red oak, an inexpensive material with an auto-ignition temperature well above the maximum curing temperature for the prepreg. Its shape was based on the modeling previously described. Then the rubber mask was cast by mixing a two-part silicone rubber material at a maximum working temperature of 315°C/598°F and pouring it into the ➔



Seeking pressure uniformity

The red arrows indicate the points at which applied pressure was measured by sensors during paddle cure. A 5.5 percent disparity in pressure across the part was observed.

By the numbers

Documented parameters measured during the comparative study of curing methods. Note the extremely low energy usage of TPC.

	Autoclave	Quickstep	TPC
Preparation time (min)	35	45	3
Curing time (hours)	8.5	4.25	4.25
Energy Usage (kWh)	77	54	<1
Consumable cost (relative ratio)	100%	96%	11%
Tooling Costs (relative ratio)	72%	72%	100%
Capital Equipment ($)	125K	550K	2K

Source: Vistex

gap between the wooden female base mold and the machined curing mold. Kuppers explains that, for the thinner four- to eight-ply demonstration parts, the rubber mask trapped sufficient heat and insulated the layup so that no heat elements were needed in the base mold. But he admits, "For thicker parts — say, 32 plies or more — we would likely need to heat the base mold as well, to ensure rapid ramp-up and uniform temperature."

The demonstration involved four-ply prepreg blanks, made with Hexcel's (Stamford, Conn.) HexPly 6K carbon/epoxy material and preformed to part shape in a diaphragm forming process. The preforms then were placed on the curing mold and covered with a release film and a breather cloth. Thermocouples were inserted between the film and the breather to monitor the temperature during cure, and pressure uniformity was measured via FlexiForce sensors (from Tekscan, S. Boston, Mass.) placed between the layup and the base mold. A pressure plate was added to a simple 10-ton, single-ram hydraulic press for better performance. Walczyk reports that sensors showed uniform temperatures over the part, and pressure measurements showed that the greatest pressure disparity across the tool was approximately 12 percent. For a prospective production part, the desired pressure was 100 psi/6.89 bar, so the actual pressure at the part surface varied from 90 to 110 psi across the part. This was better than predicted by the simulation, notes Kuppers.

At this point, the process was proven further through actual production of composite kayak paddles. For this mold set, the FEA model predicted less than a 10 percent disparity in pressure across the paddle, a result of significant advances in the optimization algorithm. Again, an aluminum tool mold was designed with CAD and machined. It was polished, sealed with Frekote mold release from Henkel Corp. (Rocky Hill, Conn.) and then fitted with two 100W flexible heaters. The base mold was machined from Modulan epoxy tooling board supplied by McCausey Lumber Co. (Roseville, Mich.), and the silicone rubber mask was designed via the iterative modeling process previously described. The paddle comprised eight plies of woven 3K carbon/epoxy prepreg, supplied by Gurit (USA) Inc. (Bristol, R.I.). When the pressure distribution was measured during cure by sensors distributed across the paddle, a mere 5.5

percent disparity was noted, and Kuppers reports that the temperature variation across the part was virtually nil.

Favorable comparisons

Vistex also conducted a comparative study in which the benchmark part was cured via three methods: with TPC, in an autoclave and in the out-of-autoclave curing process developed by Quickstep Technologies (Bankstown Airport, New South Wales, Australia, and Dayton, Ohio). Autoclave cure was done by Kaman Composites – Vermont Inc. (Bennington, Vt.), and the Quickstep cure was done by Quickstep Composites LLC in Dayton (see "Learn More," below). The comparative costs for the three methods were tallied, and the parts were cut into coupons and destructively tested to compare their mechanical properties. The results show that the rapid temperature-ramping capabilities of TPC and Quickstep reduce cure time to the minimum required by the prepreg manufacturer. TPC cure was accomplished in 4.25 hours, compared to roughly 8.5 hours in the autoclave.

Kuppers asserts, "The high temperature ramp rates achievable with TPC can reduce cycle times for any resin system." Dimensional tolerances on the TPC part were comparable to the autoclaved part, with minimal to no surface defects. Further, TPC used far fewer consumables because it requires no vacuum bagging, in contrast to the other methods, so layup is fast and straightforward. Most telling, the energy consumption for TPC was nearly two orders of magnitude less than for the autoclave and Quickstep process, attributable to the fact that TPC heats only half the mold (and the heat source is in direct contact with the part). Finally, the capital equipment cost for TPC is a fraction of that for the other two methods.

Although TPC offers major benefits in speed, cost and part quality, Vistex is quick to point out that more work will be necessary to scale the process for larger parts. Also, tooling costs will increase for rate production because multiple tool sets and inserts would be needed, and inserts, which reportedly perform well into the low hundreds of cycles, would need replacement in lengthy runs.

Kuppers and his colleague, Vistex COO Dr. Casey Hoffman, report that Vistex is currently investigating new part materials, including thermoplastics and bio-composites, testing thicker laminates and more complex part geometries, and considering process automation. Currently, Vistex molds prototypes for several customers in marine energy turbine, motorcycle and other markets. In the future the toolmaking technology and, alternatively, ready-to-use tools could be leased to customers.

Concludes Hoffman, "We plan to offer manufacturers a fast, very cost-effective, out-of-autoclave solution that is capable of producing an autoclave-quality part." That goal is well within reach. ■

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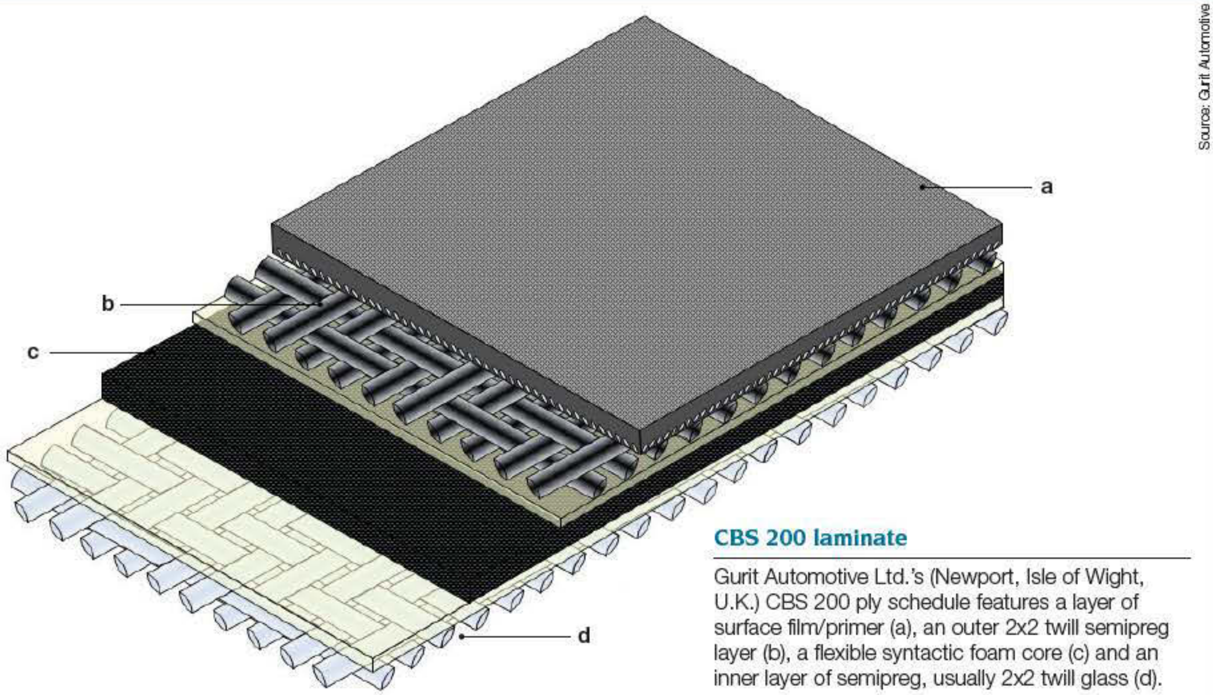
Read this article online at http://short.compositesworld.com/aFL1ccaN.

Read more about the Quickstep curing process in "An out-of-autoclave progress report," *HPC* September 2011 (p. 9) or visit http://short.compositesworld.com/2w4xwLDf.



CBS 200 laminate

Gurit Automotive Ltd.'s (Newport, Isle of Wight, U.K.) CBS 200 ply schedule features a layer of surface film/primer (a), an outer 2x2 twill semipreg layer (b), a flexible syntactic foam core (c) and an inner layer of semipreg, usually 2x2 twill glass (d).

CLASS A CFRP BODY PANELS: SIX-MINUTE CURE

Gurit CBS-based laminate/process combo makes parts with twice the thermal performance in one-sixth the time.

BY PEGGY MALNATI

With tougher emissions and fuel economy targets now in play, automakers are struggling to take weight out of vehicles without losing control of costs or sacrificing production volumes. The composites industry, in turn, is scrambling to shorten the processing times of polymers, particularly thermosets and especially those used in carbon fiber-reinforced plastics (CFRPs). Much CFRP work of late has focused on resin chemistry, to reduce the catalyzed polymer's cure duration, and on finding out-of-autoclave processes that produce quality parts but require less time, energy and secondary finishing — bogeys that have previously driven production rates down and costs up. Toward those ends, Gurit Automotive Ltd. (Newport, Isle of Wight, U.K.) has developed a new laminate material and "press process" that reportedly produces CFRP parts with nearly *twice* the previous thermal performance (200°C/392°F vs. 110°C/230°F) in button-to-button cycle times down from 60 to 10 minutes, achieving cure in a mere six minutes.

SPRINT to the finish

Called CBS 200, the new material is based on Gurit's patented SPRINT (SP Resin INfusion Technology) CBS (car body sheet) technology introduced in 2007 for Class A automotive body panels. The new product offers the low weight and Class A surface of the previous CBS 96 grade, which was developed for low-temperature (80°C/176°F) paint ovens, but the 200 version is compatible with E-Coat. Short for electrophoretic coating, E-Coat is known in Europe as KTL, a German abbreviation for cathodic dip painting (CDP). It is the high-temperature process used to bake/cure rust preventative onto the metallic body in white. Although composites don't need rustproofing, automakers prefer to attach panels at the start, not the end, of vehicle build.

The original CBS epoxy-matrix laminate is a sandwich construction: a Gurit SF 95 surface film; a carbon-fiber fabric semipreg, typically 200g/m² (0.65 oz/ft²) 3K tow in a 2x2 twill weave; a thin (0.7 mm/0.03 inch) yet flexible syntactic foam core of epoxy/glass microspheres, which increases stiffness and buckling resistance but offers inmold conformability; and another fabric semipreg, typically glass instead of carbon, in a 400 g/m² (1.31 oz/ft²) 2x2 twill weave.

A key element of the CBS system is the highly filled surfacing film/primer, which provides a resin-rich shell that blocks fiber read-through and enhances paint adhesion. Developed inhouse, the film typically is 700 g/m² (2.29 oz/ft²) by weight and features a solvent-free, hot-melt epoxy film sandwiched between fiberglass scrim and proprietary, finely woven thermoplastic scrim layers. Because it is flexible and slightly tacky, the film layer goes into the tool first and, during cure, forms an opaque, homogeneous surface.

Gurit attributes fiber read-through to a coefficient of linear thermal expansion (CLTE) mismatch between the resin and the reinforcement. The film, therefore, is formulated to have a CLTE intermediate between standard epoxy and carbon fiber. After it is cured, the panel is sandable and can be prepared and painted like metal or sheet molding compound (SMC). Because there's no solvent in the film that can be trapped during cure, voids and paint pops are greatly reduced. As a result, Gurit says, less finish work is needed and the film's surface quality is a key driver for use of this technology.

The fiber layers — whether carbon alone or carbon and glass — are single-sided semipregs that are produced, much like the surface film, by extruding a mix of epoxy and catalyst as a film and then laying woven fiber on top. Featuring carbon on the part's A surface and glass on the B surface, the thin laminate offers stiffness comparable to steel and aluminum but is less prone to twisting than an unbalanced carbon/carbon laminate with a resin-rich surface, says Gurit. The partially impregnated stack and central syntactic foam layer are reportedly less expensive and lighter than many competitive systems and offer good conformability/drapability. Indeed, laminate edges typically are rolled over a loose edge tooling bar to mimic the rolled edge that is common in stamped steel and aluminum. This eliminates postmold edge trimming.

Although the new product is based on previous SPRINT CBS technology that uses epoxy-based resin and a similar structure/ply schedule, the chemistry has changed throughout the laminate (surface film, semipregs *and* syntactic core), and scrims have been eliminated from the surface films, says Gurit's managing director Martin Starkey. The new system reportedly provides better fiber wetout, greater thermal stability/higher glass-transition temperature (T_g), faster cure *and* a very low, controllable exotherm — properties usually not found together.

Although other epoxy producers offer high-T_g grades (typically for aerospace use), the cycle time usually goes up with the T_g. Gurit's new proprietary formulation delivers high T_g with shorter cycles. Starkey also says that its epoxide expertise and long experience molding thick laminates for wind turbine blades and boat hulls helped Gurit control exotherm while significantly reducing cure time.

The previous epoxy cured in 60 minutes, offered a T_g of 110°C/230°F, and could withstand extreme ambient temperatures (e.g., those likely in a black car sitting outside on a 30°C/86°F day). The new technology cures in six minutes, offers a T_g of 200°C/392°F and, although it loses some modulus above its T_g, it can endure 10 minutes in the E-Coat oven — another step toward making CFRP panels easier to use on auto assembly lines.

Starkey notes that because it does not produce its own fiber, Gurit has the flexibility to try many fiber sources and types (e.g., nonwovens and crimps). "Fiber choice can be optimized in our process," he points out, "so we tend to source in, and that gives us a lot of flexibility to go with whatever the end-component's mechanical performance requires." In the fiber segment, he notes, "that's a benefit, because there are more interesting products and players every day."

New press process

To the new laminate technology, Gurit has added a new press process to form the panels. Previously laminates were molded in a vacuum-bag/out-of-autoclave setup that accepted a variety of tooling types (carbon composite,

Source: Gurit Automotive

Low-pressure, short-cycle press technology

To complement CBS 200, Gurit developed a new press-based molding process that uses matched-metal dies and relatively low pressure to achieve a 10-minute cycle time, a significant improvement compared to Gurit's previous vac-bag process, which took a full hour to form and cure parts.

Source: Gurit Automotive

Flexible material, faster manufacturing

Because it features semipreg and a flexible syntactic core, the CBS 200 laminate is reportedly more flexible and, therefore, has better drapeability/conformability than most prepreg laminates, so it can better conform to complex tool geometries without dry spots and bridging. The new process is expected by Gurit to produce up to 40,000 parts per year on a single tool set.

machined steel and nickel shell). To help ensure a good molded finish on the part backside, the press is fitted with *intensification tools*. These provide a better B-side aesthetic on panels such as fenders that are not bonded to an inner panel, and they ensure a consistent surface and gap between bonded panels, such as roofs and hoods. Previously, these lower-cost, rigid structures (a/k/a caul plates) were *manually* inserted between the laminate and vacuum bag, which is one big reason why the old process took 60 minutes.

To keep heating/cooling systems simple and tooling costs down, the press and materials that go into it have been designedfor processing at a constant molding temperature (200°C/392°F) — more like thermoplastics than typical thermosets — and relatively low pressures. "The preform can be hot loaded and demolded without post-cure," Starkey says. "A fast 10-minute cycle time is achievable." Unlike resin transfer molding (RTM), the new system doesn't need complex injection equipment to get resin into the tool; and the more drapable semipreg makes complex geometries easier to fill with fewer dry spots.

Although he says they're still working out the upper and lower threshold of process parameters, Starkey adds that the system's low forming pressures give his team a lot of freedom regarding tool substrate selection and this, in turn, has led to "a lot of novel ideas besides how to physically form the parts."

"We wanted to be able to maintain the same level of material performance our SPRINT CBS product is known for while reducing cost and labor content, and increasing our manufacturing capacity," Starkey sums up. "We've stripped away a lot of manual processing," he emphasizes, noting that the optimized material format reduces the degree of preforming needed to mold complex features "and delivered a net-shape part without a lot of trimming. This gives us cycle-time advantages and, therefore, access to larger-volume platforms." Assuming a 10-minute cycle, the process should produce as many as 40,000 parts per year per tool set, a rate roughly an order of magnitude faster than current thermoset CFRP processes.

Starkey's team developed the process on an in-house prototype press and small test-plaque tool and then took it out to the field and trialed it at a large OEM and a large-tier supplier using a full-size press and production tools. The results have been very promising. Starkey acknowledges that the costs and production speeds of CFRP panels are still impractical for conventional midsized and economy cars, but he feels the supersport and premium sectors are viable targets for the first application of the new laminate/process combination.

"The commercial question is, *Will the volume [of a platform] demand this process?*" Starkey notes, but adds. "All the pieces are there and this technology is ready for a commercial launch." ■

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Read this article online | http://short.compositesworld.com/WTJigQb9.

Read more about the CBS process in "Gurit CBS for the Aston Martin DBS," in *HPC's* sister magazine *Composites Technology* (*CT* February 2010, p. 24) or visit http://short.compositesworld.com/DvXgteYR.

Stingray reboot shows off Plasan parts

With the arrival of its 2014 Chevrolet *Corvette Stingray*, General Motors Co. (Detroit, Mich.) became the world's first automaker to use Class A CFRP body panels molded by Plasan Carbon Composites' (Bennington, Vt.) "pressure-press" technology.

Source: General Motors Co./Photo: © General Motors Co.

FASTER CYCLE, BETTER SURFACE: OUT OF THE AUTOCLAVE

GM is first automaker to use Class A CFRP parts from new pressure-press technology.

Source: Plasan Carbon Composites

Purpose-built plant & presses

Built specifically to mold the *Stingray's* CFRP hood and roof, Plasan Carbon Composites' plant in Walker, Mich. Is equipped with five new "pressure presses" designed and built by Globe Machine Manufacturing Co.

On Jan. 14, General Motors Co. (GM, Detroit, Mich.) introduced its 2014 Chevrolet *Corvette Stingray* reboot at the North American International Auto Show (NAIAS, Detroit, Mich.). Returning to the iconic *Stingray* name badge for the first time since it was retired in 1976, the new baseline *Corvette* is also the first production car to feature structural, Class A carbon fiber-reinforced plastic (CFRP) body panels produced via a new out-of-autoclave "pressure-press" technology. Invented by Plasan Carbon Composites (Bennington, Vt.), the process relies on equipment developed and built by Globe Machine Manufacturing Co. (Tacoma, Wash.).

The *Stingray*'s removable roof is available painted or in an exposed-weave/clear-coated version. The hood is painted to match the body. Each is formed and cured by Plasan's process 75 *percent faster* than previous autoclaved parts.

Mass-producing mass reduction

The commercial debut of the hood and roof is a significant milestone for automotive composites. Pound for pound, carbon composites are the lightest, strongest construction materials available to industry. Automakers today readily acknowledge that they offer an ideal means to reduce vehicle mass without sacrificing occupant safety or driving performance as OEMs seek to meet more stringent U.S. fuel economy standards and significantly more difficult European tailpipe emission limits. But the high cost of carbon fiber, the time and expense of autoclave processing and a lack of predictive-engineering tools have kept away all but a handful of supercar and high-end sports car builders.

At their low volumes, autoclave cure is fast enough and the manufacturer's suggested retail price (MSRP) is high enough to recoup the expense. However, when you move from a few thousand to tens of thousands of cars annually, autoclave cure becomes too slow and expensive — hence the scramble to find faster-curing resins and to develop new out-of-autoclave process derivatives.

"*Corvette* has pioneered the use of innovative, lightweight materials since its introduction in 1953 as the industry's first production car with a fiberglass body," notes *Corvette* chief engineer Tadge Juechter. "The new *Stingray* ... will continue that tradition by becoming the industry leader in high-volume use of carbon fiber. For the standard *Stingray* coupé, we'll use 18 lb [8.2 kg] of carbon fiber just on the roof and hood. Based on last year's sales of 14,132 units, *Corvette* will account for at least 238,000 lb [107,955 kg] of carbon fiber annually — and we expect to sell significantly more *Corvette Stingrays* than that."

Notably, the reborn *Stingray* and the pressure-press for its roof and hood were developed during the darkest days of the post-2008 recession. GM was in bankruptcy. Although Plasan had supplied autoclave-cured CFRP body panels for *Corvettes* since 2006, its new owners, who had purchased the automotive side of Vermont Composites Inc., were wondering why on earth they'd decided to diversify from their core defense business into the capricious world of cars. GM persevered, even renovating the *Corvette* Bowling Green, Ohio, assembly plant. Likewise, Plasan's owners invested "tens of millions of dollars" to develop the new molding process, build a new technical center in Wixom, Mich., and then build a new production facility in Walker, Mich.

Hood and roof production will occupy only half of the facility's available 170,000 ft²/15,794m² manufacturing space, leaving room for growth. Gary Lownsdale, Plasan's chief technology officer and co-inventor of the process, sees the Walker facility's mission as nothing less than an opportunity "to bring CFRP into mass production for cars."

Minimizing the makeover variables

Although the new *Stingray* panels are similar in size to those used on the previous *ZR1*, they have different contours. Plasan's president, James Staargaard says the company simplified approvals and minimized the number of variables during the changeover process by using the same resin, structural adhesive, clearcoat chemistry and laminate technology. Plasan did, however, make one significant change: the company is now hot bonding the hood's inner and outer panels. The adhesive is heated while it is robotically applied, and parts are fixtured for cure at ambient temperature. This is 72 percent faster than the oven-cure method used on the *ZR1*.

The pressure presses are fitted with 6-ft by 6-ft (1.8m by 1.8m) platens. Lownsdale says the large hood inner and outer panels and smaller roof can be molded on the same size press. Plasan uses single-sided, thin-shell nickel vapor deposition (NVD) tools from Weber Manufacturing Technologies Inc. (Midland, Ontario, Canada). A reusable bladder/canopy closes off the part's B-side. Plasan produces the bladder in-house using silicone heat-cured rubber (HCR) from an undisclosed source. The bladder's smooth surface eliminates wrinkles, read-through and other blemishes typical of vacuum bag.

Each tool features built-in oil-type heating/cooling elements and, according to Plasan, provides precise thermodynamic control without inductive mold heating. ➔

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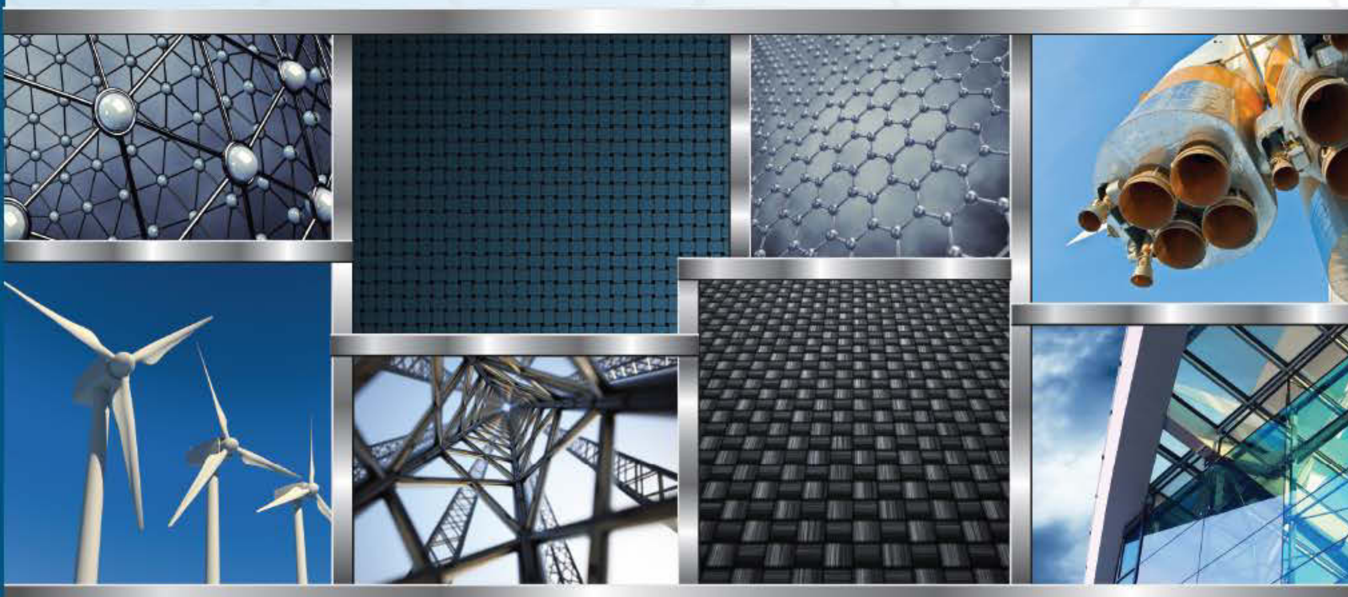

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Roof and hood tools can run in any Globe press at the Walker and Wixom sites. Most notably, Plasan developed Coupling Recognition System (CRS): When a part's tool is plugged into the press, the CRS not only automatically identifies what part the tool is designed to mold, but it also queues up the "cure recipe" (process settings) for optimum production, effectively providing plug-and-play functionality.

Maximizing the molding process

Each part is hand layed in its NVD tool on an indexing table outside the press, using prepreg from a robotically cut kit produced in another part of the facility. "Unfortunately, the technology doesn't exist yet to do automated layup of very complex geometric parts with the compound sweeps that you find in automotive," says Lownsdale. "We've successfully automated layup of simple parts, and the ability to translate that to more complex designs is one of the goals we're chasing to continually decrease total cycle time."

When layup is complete, the canopy is pulled down over the part and smoothed into place. Then the table indexes into the press chamber, and its front and rear doors close. A pressure box (slightly larger than the tool) descends from above, sealing off the top and sides of the tool and bladder. A vacuum is drawn, and a "very small column of air" completely surrounds the tool and bladder inside the box. Pressure is applied to the top of the box (and, therefore, the air column) by a hydraulic ram. In this sealed environment (which doesn't require nitrogen because the process tightly controls exotherm) the tool surface rapidly heats, enabling resin to flow quickly before crosslinking begins. This accounts for a much-improved surface finish.

Using conventional resin and laminate technology, Plasan can achieve a 10-minute cycle time with a six-minute cure, says Staargaard. But in practice the press maintains a "balanced" 17-minute cycle to avoid overproducing parts and getting ahead of the bonding, trimming and finishing stations. The process eliminates the expense of vacuum bagging materials and uses a small fraction of the energy consumed in an autoclave cycle. And the part's excellent as-molded surface has accelerated downstream operations by 80 percent. Although he is pleased, Lownsdale says the benchmark is injection-molded surface quality and speed. To that end, Plasan is working closely with major resin and prepreg producers.

Moving into the mainstream

"It's absolutely possible to make CFRP components mass producible in the auto industry," Lownsdale sums up. "Now, when we sit down and talk seriously about a CFRP component, our customer no longer says, *Prove it to me and I'll consider it*, but rather says, *How can we work together to make this happen?* ■

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Read an extended verison of this article online at http://short.compositesworld.com/V4Ty5lv4.

Link to previously published articles about the development of Plasan Carbon Composites' pressure press technology at http://short.compositesworld.com/m5tTYbcD.

Source: HPC/Photo: Jeff Sloan

SURPLUS in carbon fiber's future?

Carbon Fiber 2012

More than 100 composites professionals gathered in La Jolla, Calif., in December 2012 for CompositesWorld's annual Carbon Fiber conference.

Participants at CW's Carbon Fiber 2012 Conference see one coming as early as 2016.

One of the great attractions of CompositesWorld's Carbon Fiber conference is the outlook on carbon fiber supply and demand, anchored each year by Chris Red, principal of Composites Forecasts & Consulting LLC (Mesa, Ariz.). Over the past few years at the conference, he has consistently forecast an imbalance in the carbon fiber market: Around 2016, carbon fiber demand will outstrip supply. Not so at Carbon Fiber 2012 (Dec. 4-6, La Jolla, Calif.). Crediting quick evolution and strong growth among carbon fiber manufacturers, Red predicted that the composites industry is in for several years of carbon fiber supply that *exceeds* demand.

What's driving the trend to oversupply? There are several factors at work: new carbon fiber suppliers have entered the market; suppliers overall have increased the efficiency of their carbon fiber production; and, notably, there are signs of contraction in some markets — some are expected to consume less carbon fiber than initially anticipated.

That said, there is plenty of room for volatility, according to Red. A marked increase in the use of carbon fiber in the automotive sector, uncertainty in the market for wind turbine blades, new members in the formerly exclusive club of carbon fiber producers — some combination of these or other factors could unbalance the supply/demand equation yet again. As an example of one of those "other" factors, problems with a lithium-ion battery system has — as *HPC* went to press — grounded the fleet of Boeing 787 *Dreamliners* indefinitely, and although Boeing sees no effect on 787 production, industry observers differ (see news item on p. 15). The bottom line is this is an exciting, if nerve-wracking, time to be a carbon fiber supplier and consumer.

The numbers

The charts, tables and graphs that accompany this story outline in detail Red's carbon fiber forecast for the next few years. Here's the big picture: In 2012, the global nameplate capacity of carbon fiber was 111,785 metric tonnes (more than 246.4 million lb), comprising 72,145 metric tonnes (>159.0 million lb) of small-tow fiber (3K to 24K) and 39,640 metric tonnes (>87.3 million lb) of large-tow fiber (>24K). By 2016, global nameplate capacity will rise to 156,845 metric tonnes (>345.7 million lb). Of that total,

Table 1	Global Carbon Fiber Production Nameplate Capacity vs. Actual Output		
Year	Nameplate Capacity	Actual Output	Knockdown
	metric tonnes		
2012 (est.)	111,785	67,071	60%
2016 (est.)	156,845	106,655	68%
2020 (est.)	169,300	121,896	72%

Table 2	Global Carbon Fiber Production Demand, by Market, 2012-2020								
Market	2012	2013	2014	2015	2016	2017	2018	2019	2020
	metric tonnes								
Aerospace	7,800	9,220	11,550	13,090	13,670	14,340	16,260	18,100	19,570
Consumer	9,990	10,280	10,530	11,110	11,790	12,410	12,770	13,110	13,730
Industrial	29,430	33,060	38,370	43,280	49,280	51,380	58,130	63,100	69,160
Total	47,220	52,560	60,450	67,480	74,740	78,130	87,160	94,310	102,460

Table 4	Global Carbon Fiber Production, by Tow Size, 2012-2020		
Year	Small Tow (3k-24k)	Large Tow (>24k)	Total
	*metric tonnes**		
2012	72,145	39,640	111,785
2013	79,845	44,640	124,485
2014	94,345	46,200	140,545
2015	101,645	48,700	150,345
2016	106,145	50,700	156,845
2017	109,145	51,700	160,845
2018	111,145	52,700	163,845
2019	113,145	53,700	166,845
2020	115,600	53,700	169,300

Table 3	Global Carbon Fiber Production Demand, by Fiber Form, 2012-2020*								
Market	2012	2013	2014	2015	2016	2017	2018	2019	2020
	metric tonnes								
Woven Fabric	20,770	24,220	28,840	32,590	36,880	38,470	43,690	47,630	53,640
Thermoset UD Prepreg	42,420	45,950	49,300	52,950	57,280	61,160	66,210	71,000	76,470
Thermoset Fabric Prepreg	36,330	41,190	49,850	56,960	61,400	62,780	69,390	74,290	78,640
Thermoplastic Prepreg	6,830	9,010	9,460	11,280	13,070	14,100	18,830	23,830	27,340
Raw Fiber	19,990	21,240	24,880	27,000	30,440	31,760	35,870	37,140	40,770
Molding Compounds	25,070	26,150	30,450	34,840	38,960	40,630	41,290	44,850	44,580
Total	151,410	167,760	192,780	215,620	238,030	248,900	275,280	298,740	321,440

*Weight figures for the converted fiber forms charted in Table 3 include resin weight in the case of prepregs.

Source: Composites Forecasts and Consulting LLC

small tow will account for 106,145 metric tonnes (>233.0 million lb), and large tow, will account for 50,700 metric tonnes (>111.7 million lb). By 2020 (Red characterizes this as highly speculative), the global nameplate capacity will be 169,300 metric tonnes (>350.9 million lb). Small tow will make up 115,600 metric tonnes (>254.8 million lb);, and large tow, 53,700 metric tonnes (>118.3 million lb).

Tempering these figures is the caveat associated with any discussion about carbon fiber manufacture: *knockdown*. This is the difference between the nameplate capacity of a carbon fiber line and its actual production capacity. Actual output is always smaller due to inefficiencies in the manufacturing process. The good news is that Red expects manufacturing efficiency to *increase* substantially over the next decade. For 2012, he estimates efficiency was about 60 percent. By 2016, that number jumps to 68 percent, and by 2020, it could reach 72 percent. This means, of course, that a global nameplate capacity of 109,635 metric tonnes (> 241.7 million lb) in 2012 represents 65,781 metric tonnes (> 145 million lb) of actual carbon fiber.

On the demand side of the market, Red says the 2012 global carbon fiber demand in all markets was 47,220 metric tonnes (>104.1 million lb). By 2016, that number is expected to increase to 74,740 metric tonnes (>145 million lb) and then rise to 102,460 metric tonnes (>145 million lb) by 2020. Even with knockdown factored in, the 2016 demand will fall short of actual supply by about 25,000 metric tonnes (>145 million lb). And in 2020, the demand will fall short of actual supply by about 12,000 metric tonnes (>26.4 million lb).

Behind the numbers

The market forces that drive carbon fiber supply and demand are numerous and complicated, as Red quickly admits. It's evident, however, that a few indicators, with little change, have the capacity to substantially shift the carbon fiber market.

Topping the list is the automotive market, which appears to be in the early stages of a long-term and substantial increase in the application of carbon fiber to structural and semistructural production vehicle components. Several presentations at Carbon Fiber 2012 touched on manufacturing processes that, with additional fine-tuning, could move carbon fiber into high-volume automotive manufacturing for mainstream cars. Red pointed in particular to the BMW *i3* all-electric, four-door passenger car, due out later this year at an estimated volume of 30,000 units per year. It features a first-of-its-kind carbon fiber passenger cell, the fiber for which is supplied by a BMW/SGL partnership that has constructed a purpose-built carbon fiber plant in Moses Lake, Wash. (see "Learn More," p. 52) Red noted at the conference that the BMW *i3* "application has significant potential to be as large as aerospace for carbon fiber, if not larger."

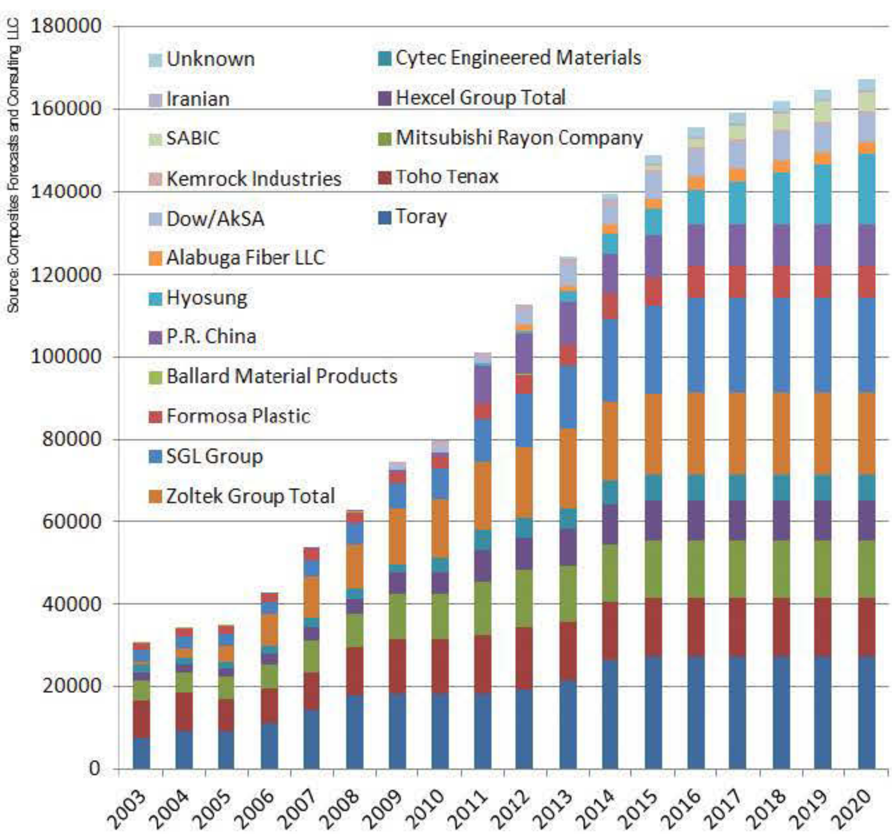
Next on the indicator list is wind energy, where carbon fiber's future is most uncertain. Carbon fiber is used primarily in large wind blades, and because this sector's growth focused increasingly on *offshore* wind farms, it seemed — as recently as a year ago — that wind blade manufacturers would gobble up carbon fiber in runaway amounts. Red noted, however, that the recent expiration of the wind energy production tax credit (PTC) in the U.S., with its renewal the morning after for a mere year, and a Beijing-dictated ramp-down of wind energy expansion in China have put a damper on things. Still, Red estimates that the wind energy sector consumed 15,000 metric tonnes (33 million lb) of carbon fiber in 2012 and is on track to demand 23,440 metric tonnes (51.6 million lb) in 2016 and 36,840 metric tonnes (81.2 million lb) in 2020. This more moderate prediction, if fulfilled, will keep wind energy in the top spot, by far, as the largest carbon fiber consumer in the world. But the numbers will fall short of previous expectations. In 2010, Red predicted the wind energy carbon fiber consumption at 64,000 metric tonnes (141 million lb) by 2019.

A third indicator poses uncertainty for the carbon fiber market. Lockheed Martin's F-35 *Lightning II* fighter jet features an all-composite skin, but it has suffered delays and cost overruns that are suppressing the orders outlook. "We'll not see the annual unit production rates of even a few years ago," Red suggested at the conference.

Making things interesting on the supply side is a host of new carbon fiber manufacturers, including Hyosung (pronounced "cho-sung," Seoul, S. Korea), SABIC (Riyadh, Saudi Arabia), DowAksa (a joint venture of Dow Chemical, Midland, Mich., and AKSA, Istanbul, Turkey), Alabuga Fiber LLC (Moscow, Russia), Kemrock Industries (Gujarat, India) and the government of Iran. All of these new supply sources provide (or will soon provide) *industrial-grade* (standard- and intermediate-modulus) fiber intended for use in markets other than aerospace. Applications of industrial-grade fiber (>24K) are growing at a faster rate than those for high-modulus, aerospace-grade (3K-12K) product.

New players are not expected to seriously challenge longtime producers in the short term. Toray (Tokyo, Japan) is expected, throughout the forecast, to remain the largest carbon fiber supplier, but Red showed a cluster of other suppliers vying for second place, including Zoltek (St. Louis, Mo.), Toho Tenax (Tokyo, Japan), Mitsubishi Rayon Co. Ltd. (Tokyo, Japan) and SGL Group (Wiesbaden, Germany). And by 2016, Red estimates, the two largest carbon fiber producers will be Toray and SGL Group.

The confluence of new players and tempered demand has set up a likely surplus that will inevitably affect fiber pricing. "With this scenario," said Red, "I would think that, unless the market grows significantly faster than I have projected, this excess capacity will keep overall pricing very competitive and may force a shakedown of the supply chain. Wind energy obviously is a big contributor to near-term issues, and the current subsidy policies are creating artificial booms and busts in the system, in both the U.S. and China."



Nameplate numbers

Estimated carbon fiber nameplate capacity by manufacturer through 2020.

Price and precursor

Fiber pricing was a hot topic at Carbon Fiber 2012. Conference participants considered whether the industry can ever achieve the mythic $5/lb threshold that some would-be consumers of carbon fiber — among them, carmakers still reluctant to use carbon fiber in structural applications — claim would open up a variety of new applications.

For several years the belief has been that the industry can and should develop a less-expensive alternative to polyacrylonitrile (PAN) precursor, which makes carbon fiber notoriously expensive. Find a cheaper precursor, the thinking goes, and cheaper carbon fiber will result. Oak Ridge National Laboratory (ORNL, Oak Ridge, Tenn.) has been studying alternate precursors for years. Although lignin was a possibility, the lab now is looking at polyolefin with partners Dow Chemical and Ford Motor Co. (Dearborn, Mich.).

Some carbon fiber manufacturers at the conference expressed skepticism that a non-PAN material can provide the same chemistry that makes carbon fiber so effective — particularly high-modulus carbon fiber for use in high-performance applications. But speaker Jai Venkatesan, Dow's director of materials science and engineering, admitted that a year ago he, too, was pessimistic about the potential of polyolefin as a viable precursor. "However, we are confident now that we can turn the right knobs to spin the polyolefins in the right way. We think that this is possible." He added that Dow estimates the carbon fiber yield from polyolefins, like polyethylene and polypropylene, might approach 86 percent.

Although it is by no means clear if this could result in $5/lb carbon fiber, a non-PAN precursor could certainly lead, at some point, to the manufacture of less-expensive fiber. Ross Kozarsky, senior analyst at Lux Research (Boston, Mass.), reported that his research indicates non-PAN materials do have a future as a precursor, but production of fibers from them would require innovations in oxidization and carbonization during the carbon fiber manufacturing process and would benefit only those who make standard- and intermediate-modulus fiber.

BMW sets production CF car debut

The BMW *i3* all-electric passenger car, due out later this year, is the first production vehicle to use an all-carbon-fiber passenger cell. Other automakers are looking to use carbon fiber in similar applications and are likely to follow BMW's supply model, which includes a joint venture with carbon fiber manufacturer SGL Group.

Source: BMW/SGL

"I do not think high-modulus carbon fiber is a candidate for the alternative precursor work," Kozarsky said, pointing out that "this work is driven by the ability to sacrifice performance for cost reduction." That's a tradeoff automakers can make because they have less stringent performance requirements. But it's not an option in the aerospace market. "Applications that require high-modulus fiber are not a good opportunity for applying the alternative precursors." Kozarsky also noted that current precursor efforts are focused on textile-grade PAN, which is less expensive. He said that ORNL/Dow and SGL Group, through Fisipe, the Barreiro, Portugal-based precursor manufacturer it recently acquired, are on this path. Kozarsky believes ORNL's textile-grade PAN-based carbon fiber line will come online in 2013 and achieve carbon fiber unit costs of about $19.30/kg ($11/kg = $5/lb). This will lead, by 2016, to development of precursor based on melt-spun PAN and carbon fiber prices of $15.90/kg. By 2017, he said, assuming

Source: Airbus

A350 take-off should lift market to unprecedented altitude

The Airbus A350 XWB is nearing reality. Its first test flight aircraft and static test aircraft are in the assembly stage. Like the Boeing 787, the A350 XWB uses carbon fiber in the wings, wing box, flight-control surfaces, empennage and fuselage. No longer the largest market for carbon fiber (that title now goes to wind energy), aerospace is still considered the most important. Analysts at the conference forecast continued growth in a robust aerospace market.

advances on the oxidization and carbonization side, expect a polyolefin-based PAN and carbon fiber price potential of \$10.50/kg — *below* the \$11/kg threshold.

"None of these innovations, taken alone, can reduce the cost enough," Kozarsky warned. "It must be a combination of technology and innovation." Further, a new precursor might change the chemistry of the resulting fiber. "Maintaining compatibility between the carbon fiber and the resin matrix will be critical."

The carbon fiber manufacturing industry is already segregating itself by end market, with standard- and intermediate-modulus fiber designated for industrial markets and high-modulus fiber designated for aerospace markets. The development of a non-PAN precursor would insert itself into this split and become associated, by virtue of chemistry and function, with carbon fiber in industrial market applications.

Markets, applications, opportunities

The commercial aerospace market remains the most critical and highest profile application of high-modulus carbon fiber. With the Boeing 787 on the market and the Airbus A350 XWB in assembly and undergoing preparations for flight testing, it *appears* that the carbon fiber supply chain is headed into a period of stability. However, aerospace development outside the Boeing/Airbus spotlight, and possible new Boeing/Airbus projects, signal a dynamic marketplace.

Commercial aircraft orders are on the rebound, Red noted, after they peaked in 2007 at 3,487 and bottomed out at 663 during the recession in 2009. Boeing and Airbus reported strong sales in 2012 (Boeing had 1,203 orders; Airbus had 914) and healthy backlogs through 2018. Red estimates that commercial composite aerostructures were about 9.4 million lb (4,264 metric tonnes) in 2011 and 10.4 million lb (4,717 metric tonnes) in 2012. Of this, carbon fiber composites accounted for about 85 percent. About 35 percent of composite aerostructures are manufactured using automation, Red estimates. That number is expected to increase to 83 percent by 2020.

Beyond the 787 and A350, notable composite aerostructures in the works include the wing, empennage and flight-control surfaces on single-aisle commercial aircraft: the Bombardier C*Series*, the Irkut MS-21 and the COMAC C919. On the military side, carbon fiber is key to the Lockheed Martin F-35 *Lightning* II fighter, the Airbus A400M airlifter, the Embraer C-390 transport, the Eurofighter EF-2000 and the Northrop Grumman RQ-4 *Global Hawk* unmanned aerial system.

The big question at every Carbon Fiber conference over the past few years has been whether or not carbon fiber composites will win a place on the fuselage of the next-generation single-aisle aircraft that will replace the Boeing 737 and the Airbus A320. The answer is *maybe*. Speaker Peter Zimm, principal of aviation consultancy ICF SH&E (Fairfax, Va.), noted that carbon fiber makes good sense in aircraft wings and *many* fuselages, but the skin thickness of a single-aisle craft, coupled with fiber placement laydown rates, makes aluminum a competitive option. Zimm says aluminum still makes up 48 percent of aerospace raw material demand, although buy weight is still a factor — the buy-to-fly ratio of carbon fiber is highly favorable. Although next-generation single-aisle aircraft from Boeing and Airbus are still on the drawing board, engineers at both companies are already monitoring the carbon fiber industry, looking for the advancements in material and process capabilities necessary to tip them toward composites.

Returning to solid ground, the next big thing in the carbon fiber industry is the automotive end-market. All eyes, for the moment, are fixed on the BMW *i3*, which represents a paradigm shift for composites use in a production vehicle and may prove to be a bellwether for other carmakers as they contemplate a similar use of carbon fiber.

However the automotive industry evolves, what's clear is that the manufacture of carbon fiber automotive structures will require a robust, high-speed process that, even if it can't mimic metal stamping, must provide cycle times of just a few minutes.

Several presenters emphasized such advancements. Globe Machine Manufacturing Co. (Tacoma, Wash.) was an attention grabber. Ron Jacobson, corporate projects manager, and Lloyd Champion, director, aerospace and industrial sectors, reported on Globe's work with Plasan Carbon Composites (Bennington, Vt.) to develop an out-of-autoclave, high-speed, single-tool pressure press for the manufacture of Class A carbon fiber composite automotive parts. The machine, which features an enclosed and sealed processing chamber, offers a 17-minute part-to-part cycle time, 0 to 350 psi, 80 psi/min ramp rate, 110°F to 660°F (43°C to 288°C) direct heating, 900°F/482°C indirect heating, 28 inches mercury of vacuum pressure and the ability to accommodate a variety of part types and sizes, depending on the chamber size and shape. Jacobson emphasized that the machine is neither a compression molding device nor an autoclave (see the related story on p. 42).

Plasan uses the machines to mold parts for the 2014 Corvette *Stingray* at its facility in Walker, Mich. *HPC* learned that after the carbon fiber prepreg is laid up on the tool, it is covered and sealed with a reusable silicone "canopy" about 0.5 inch/12.7 mm thick. After the tool is loaded into the sealed chamber in the Globe press, pressure is provided by a pressurized air mass (<150 psi) that surrounds the tool and compacts the prepreg while it is heated by the tool.

Jacobson and Champion say the machine can process autoclave or out-of-autoclave thermosets, has applicability to aerospace manufacturing and could be used to process thermoplastics as well. Globe is testing aerospace parts in 2013 and hopes to receive an OEM process procedure approval for aerospace use sometime in early 2014.

Tapping a similar vein was Dale Brosius, president, Quickstep Composites LLC (Dayton, Ohio), who reviewed his company's automated through-thickness infusion and rapid-cure process. It uses resin spray transmission (RST) in a process that, Brosius says, approximates semipreg. In RST, the user starts with an open, empty mold. The mold is sprayed with a thermoset resin. A carbon fiber fabric preform is placed over the sprayed mold surface. The mold is then closed and the part is cured. The system, says Brosius, offers rapid heating and cooling (30°C to 40°C/min), 10-minute part-to-part cycle time, low tooling costs, energy efficiency, easy automation and parts with Class A surfaces. The material costs are said to be 20 to 40 percent less than prepreg, and parts can be either painted or clearcoated. Quickstep is selling and licensing the technology globally and, Brosius added, has placed a machine that, at *HPC* press time, is set to begin operation in the first quarter of this year.

Exhibitor Dieffenbacher North America (Windsor, Ontario, Canada) introduced its high-pressure resin transfer molding (HP-RTM) process, aimed at manufacturing automotive carbon fiber composites. Dieffenbacher officials at the conference said the company has developed machinery to automate fabric preforming, molding and finishing. Molding is performed at pressures of 80 to 100 bar (1,160 to 1,450 psi) and offers part-to-part cycle times of about three minutes. The process, said Dieffenbacher, is being used by a European automotive OEM to manufacture B-pillar structures for a production vehicle.

Next year, Tennessee

Other presentations at the conference covered a comparison of metallic and composite wings, design and engineering of large antenna structures, carbon fiber use in electricity transmission lines, automated dry fiber placement and design of reinforcements for damage tolerance. Check online at www.compositesworld.com for exclusive reports on these presentations.

Carbon Fiber 2013 has already been scheduled for Dec. 9-12 in Knoxville, Tenn., and will include a tour of Oak Ridge National Laboratory. Visit www.compositesworld.com and click "Conferences" for more information and to register for an e-mail service that will provide updates on the event. ■

CW LEARN MORE @ www.compositesworld.com

Read this article online at http://short.compositesworld.com/WDizAr0I.

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.

CALENDAR

March 11-12, 2013	SAMPE Europe 2013 (SEICO 13) Paris, France I www.sampe-europe.org
March 12-14, 2013	JEC Europe 2013 Paris, France I www.jeccomposites.com
March 19-21, 2013	Composites Manufacturing 2013 Long Beach, Calif. I http://composites.sme.org/2013
March 19-21, 2013	Techtextil North America 2013 Anaheim, Calif. I www.techtextilna.com/ show_profile.html
April 9-11, 2013	Aircraft Interiors Expo 2012 Hamburg, Germany I www.aircraftinteriorsexpo.com
May 5-8, 2013	Windpower 2013 Conference and Exhibition Chicago, Ill. I www.windpowerexpo.org
May 6-9, 2013	SAMPE 2013 Long Beach, Calif. I www.sampe.org/events/ 2013LongBeachCA.aspx
May 20-25, 2013	13th International Symposium on Nondestructive Characterization of Materials Le Mans, France I www.cnde.com
May 30-31, 2013	Forum de la Plasturgie et des Composites Paris, France I www.forum-plasturgie- composites.com
June 10-13, 2013	RAPID 2013 Pittsburgh, Pa. I rapid.sme.org/public/enter.aspx
June 11-12, 2013	7th International CFK-Valley Stade Convention Stade, Germany I www.cfk-convention.com
June 18-20, 2013	Alabama Composites Conference (ACC 2013) Birmingham, Ala. I www.uab.edu/composites
July 28-Aug. 2, 2013	ICCM19 – 19th International Conference on Composite Materials Montreal, Quebec, Canada I www.iccm19.org
Sept. 17-19, 2013	IBEX 2013 Louisville, Ky. I www.ibexshow.com
Sept. 18-20, 2013	ICOLSE – International Conference on Lightning and Static Electricity Seattle, Wash. I www.icolse.us
Oct. 21-24, 2013	SAMPE Tech Conference Wichita, Kan. I www.sample.org/events

See more events at www.compositesworld.com/events

APPLICATIONS

Award-winning urban bicycle frame made from toughened prepreg

Uber design house UBC GmbH (Murr, Germany) counts among its clients Formula 1 racing teams and automakers Porsche, Bugatti and Audi. When UBC applied its accumulated expertise to a completely new urban bicycle concept, company CEO Ulf Bräutigam says, "We gave our designers carte blanche ... telling them they could more or less ignore the bicycle production rulebook." Called the *coren*, it comes in three models: *Single Speed*, *Pedelec* (electric version) and *Fixie*. The innovative frames, with flattened top and down tubes, were drafted by UBC designer Christian Zanzotti, resulting in a low overall bicycle weight of 7.7 kg/17 lb in the *Single Speed* version.

Source: UBC GmbH/Photo © UBC GmbH

UBC turned to **Cytec Industrial Materials** (formerly Umeco, Heanor, Derbyshire, U.K.) to supply autoclave-cure prepregs that could deliver the necessary mechanical performance and impact resistance. The company chose Cytec's trademarked MTM49-3, an 80°C to 160°C (176°C to 320°F) cure, toughened epoxy resin reinforced with high-tensile-strength woven and unidirectional carbon fiber, and compatible adhesive film. UBC technicians hand layed the prepregs in aluminum tooling, taking 40 hours to complete one frame.

Sebastian Wegerle, UBC's product and marketing manager, says, "We selected Cytec's prepregs because they are reliable, have a good reputation in the motorsport and aviation sectors, and we were able to choose from a wide range of fibers and resin systems to provide the best material properties." Says UBC engineer Marco Noack, "The frame ... is manufactured in a cleanroom, in accordance with motorsport and premium-vehicle construction standards."

ISPO MUNICH, a sports business trade show, recently bestowed on the *coren Single Speed* its 2012 ISPO Brand New Award. ■

NEW PRODUCTS

Automated nondestructive inspection

NDT Solutions Inc. (NDTS, New Richmond, Wis.) and **Genesis Systems Group** (Davenport, Iowa) have teamed up to develop automated robotic nondestructive inspection (NDI) systems. One result is the NSpect 210, a two-station, 6-axis robotic work cell designed for automated NDI processes. The NSpect family has been developed to provide cost-effective, accurate inspection solutions for large volumes of parts. The system combines ultrasonic inspection data with robot positional data and presents it as A-scan, B-scan and C-scan images. **www.ndtsolutions.net; www.genesis-systems.com**

Ply-based modeling software plug-in

PlySim Ltd. (Edinburgh, Scotland, U.K.) has released FEMPLY Pro, a composite ply-based modeling software plug-in for **Siemens PLM Software's** (Plano, Texas) FEMAP Pre and Post Processor. Because it is fully integrated into FEMAP and makes use of FEMAP's Global Ply capabilities, FEMPLY facilitates tabular definition of whole component laminate schedules, closely following manufacturing processes within what is said to be a simple, intuitive user interface. Multiple plies can be edited in one operation and remapped onto a new mesh after mesh refinement. The release of FEMPLY Pro augments the FEMPLY product range with the addition of the following:

- Ply draping to account for fiber angle deviation during the manufacturing process and to verify planned production processes, reducing the need for modifications or redesign late in the manufacturing process.
- Flat pattern export, enabling the user to directly extract 2-D CAD ply shapes for use in ply booklets or cutting patterns, enhancing the accuracy and reproducibility of the component.
- Postprocessing to Hill, Hoffman, Tsai-Wu, Max Stress, Max Strain, Puck and LaRC02 failure theorems with output vectors by Layer, Global Ply and Maximum. FEMPLY Pro also offers Critical Ply and Fibre Angle output vectors to quickly and easily identify critical areas.

www.plysim.com; www.plm.automation.siemens.com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Mobile video collaboration system

Librestream (Winnipeg, Manitoba, Canada) has developed Onsight, a mobile, video-based "collaboration system" that reportedly enables companies to connect internal experts to remote locations in real time, with multiple layers of security to keep the content safe. Users can send and receive live video and audio, share video or voice files, perform *telestration* (onscreen drawing) and transfer other images, enabling feedback from field staff, external suppliers and customers that enables them to assess operations and resolve issues. The Onsight system comprises three main components:

- Three models of handheld, wireless, touch-screen devices: Onsight 1000, Onsight 2000 and Onsight 2000EX. The latter has Zone 2 hazardous location approval, making it safe for use in oil and gas refineries, chemical processing plants, aircraft hangars and near gas pipelines.
- Onsight Expert software, which enables in-house personnel to communicate with field staff from desktop computers.
- Onsight Management Suite software, which provides system administrators with centralized management tools for their Onsight system.

The system can be used virtually anywhere because devices are connected via wireless, satellite and cellular networks. The devices' video cameras are hardened for durability, can provide close-up images with a 10-mm macro zoom and a 10x optical zoom and can accept external devices, such as a microscope or borescope, to send additional visuals. All communication and data is encrypted to provide tight security. The audio features include a built-in speakerphone and microphone and a headset. All participants in the discussion can perform two-way on-screen drawing. For recordkeeping, the system provides bidirectional video recording and still-image capture. The Expert software enables in-house control of the camera functions on a remote device, including illumination, zoom and focus controls to ensure clear visuals during image transmissions from the field. The software also enables video and audio conferencing. **www.librestream.com**

Online drilling database

Cutting tool and tooling systems manufacturer **Sandvik Coromant** (Fair Lawn, N.J.) has debuted its Online Drilling Knowledge Hub at www.drillingknowledge.com, a Web site dedicated to optimizing drilling processes and customizing results to the user's needs. Sandvik notes that holemaking has the potential to make — or break — an operator's productivity and profitability. Resources on the site include a cost-per-hole calculator and a drilling product selector meant to match appropriate drills to any application. Users can browse through in-person events and training opportunities that are held in Application and Productivity Centers nationwide. The full drilling resource library is a compendium of articles, case studies, Webcasts and videos depicting common drilling obstacles and solutions. **www.drillingknowledge.com**

High-speed machining center

The M8 Cube from **DATRON Dynamics** (Milford, N.H.) is a next-generation, high-speed machining center designed to reduce the number of parts and the overall cost of the center and ultimately to simplify both service and support. Brushless, direct drives provide faster acceleration, feed rates up to 866 inches/min and shorter cycle times. A 3-kW, 40,000-rpm, liquid-chilled spindle delivers increased horsepower for heavier machining and has the flexibility to mill a wide range of materials. HSK-E 25 tool holders are said to offer precision and less than 1 micron run out. The M8 Cube has a footprint of 69 by 69 inches (1,253 by 1,253 mm). It features a work area of 40 by 28 by 9 inches (1,016 by 711 by 229 mm). The center is controlled by dynamic Windows-based software that has the flexibility to integrate with third-party software and automation systems, and it features operation indicator lights built in to the gantry and control deck to indicate machine status. Other options include a spray-mist coolant system, integrated 3-D probing and automatic tool changers with up to 30 stations and tool-length sensing. **www.datrondynamics.com**

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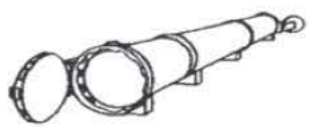

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PRODUCT & LITERATURE SHOWCASE

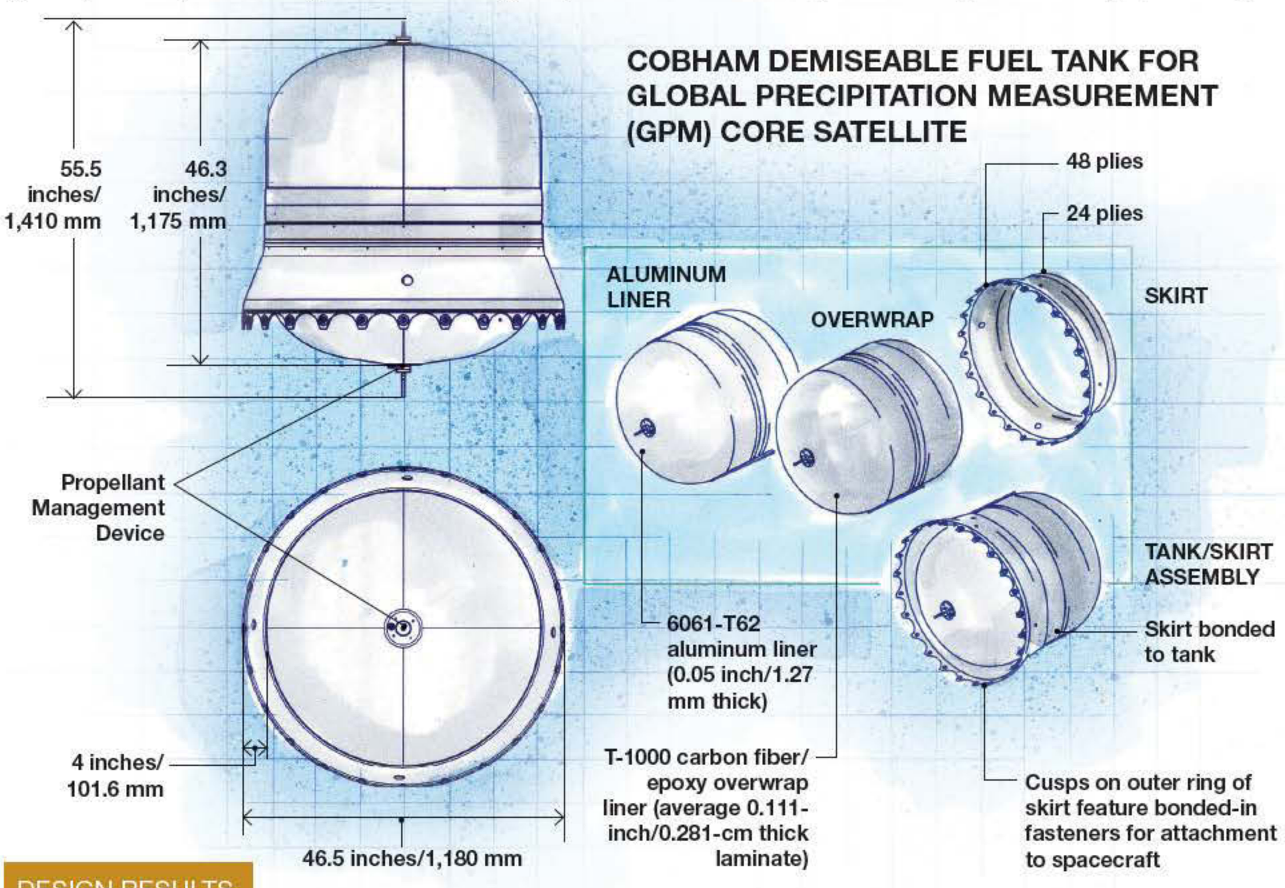
SPACE MISSION MAXIMIZED

CFRP design and manufacturing flexibility prove key in first spacecraft

In 2008, the U.S. Navy spent tens of millions of dollars to shoot down a 5,000-lb/2,268-kg NROL-21 satellite that had lost power and would soon plummet to earth with hazardous fuel inside. Although the National Aeronautics and Space Admin. (NASA, Washington, D.C.) had already forged international agreements and policies with its partners to reduce the threat of falling space debris, this event brought the issue into sharp relief for space agencies globally and the public at large.

"It became necessary to develop some method for disposing of the spacecraft," says Robert H. Estes, a lead engineer at NASA's Goddard Space Flight Center (Greenbelt, Md.). "We decided the best way to do this is to ablate the spacecraft upon reentry, resulting in a very small amount of debris left that could harm people or the environment." Thus, when Goddard began work on the Global Precipitation Measurement (GPM) Core satellite (see "Learn More," p. 64), a key design requirement was *demiseability* — minimizing the structure's ability to survive reentry.

Demiseability offers more than ground safety. Normally, a spacecraft must be brought down while it can still be controlled during reentry, but a fully demiseable spacecraft needs no propellant for reentry, so the propulsion system can be simplified or eliminated, and the craft can stay in orbit until its propellant is expended. This increases overall satellite cost-efficiency by extending mission length, reducing the



DESIGN RESULTS

- Composite overwrap enables use of an aluminum liner thin enough to disintegrate upon reentry, light enough to meet weight restrictions and strong/stiff enough to survive launch.
- To accommodate a late-program modification, composites tailorability permitted rework of the winding design rather than the expensive tooling remake necessary for all-aluminum or titanium construction.
- The carbon fiber overwrap helped Cobham to beat the program schedule, hit cost targets and lengthen spacecraft mission life, reducing the frequency of satellite replacement.

VIA MINIMIZED SURVIVABILITY

fuel tank designed to disintegrate upon reentry.

BY GINGER GARDINER
ILLUSTRATION / KARL REQUE

frequency of satellite replacement and eliminating the need for controlled reentry planning, training and contingency operations. Although the GPM Core is not fully demiseable — it is a *low-debris* spacecraft, and some propellant will be needed for reentry control — its fuel tank is.

"About 10 years ago, we started looking at how to develop a demiseable tank," says Estes, who heads the GPM tank effort at NASA. Initial analyses showed that tanks made of traditional titanium or stainless steel — either as a monolithic material or as a liner for a composite-overwrapped pressure vessel (COPV) — would not demise, but an overwrapped aluminum liner would. Four tank vendors were contracted to produce a variety of realistic, flightworthy tank designs based on projected GPM requirements. Cobham Life Support (Westminster, Md.), the breathing and life support equipment supplier for every U.S. astronaut since John Glenn, won the contract to help finalize the design and then build and qualify the tank. The baseline Cobham started with included a thin (less than 0.05 inch/1.27 mm) 6061-T62 aluminum liner overwrapped with T1000 carbon fiber (Toray Carbon Fibers America Inc., Flower Mound, Texas) impregnated with EPON 862 bisphenol-F toughened epoxy resin (Momentive Specialty Chemicals, Columbus, Ohio) to an average thickness of 0.111 inch/0.281 cm. These materials were chosen because they were already qualified for space applications and had a history of successful use.

"This is a traditional materials combination for firefighter breathing tanks," says Robert Grande, Cobham Life Support's business manager. But that did not make it challenge free. He explains, "Aluminum has never been used before in a Propellant Management Device on a spacecraft." A Propellant Management Device (PMD) is a low-gravity wick that uses surface tension forces to collect propellant and draw it to the tank outlet for expulsion. Cobham found that with appropriate surface treatment, aluminum functioned well as the PMD material, but as a monolithic tank material it couldn't meet demiseability, pressurization, structural load *and* weight requirements. An aluminum liner thin enough for demiseablility necessitated a composite overwrap.

Demiseable at Earth's atmosphere re-entry

Cobham Life Support's (Westminster, Md.), and NASA Goddard Space Flight Center's (Greenbelt, Md.) spacecraft fuel tank. Designed to disintegrate upon reentry, it is also the first spacecraft fuel tank to use a carbon fiber composite-overwrapped aluminum liner.

Engineering the overwrap ...

Although the overwrap was conventionally filament wound and oven cured, the winding design presented challenges. "The tank had to handle stresses from the weight of the fuel and pressurization of the tank," says engineering manager Rich Pemberton, "but also maintain a very careful balance between the stresses in the carbon fiber and those in the aluminum liner to assure sufficient fatigue life and burst strength while still remaining thin enough to meet weight and demiseability requirements."

Cobham's solution was to tailor the overwrap so the stresses were optimized and the burst strength of the tank was achieved without adding unnecessary material. Tailorability provided solutions to other problems as the design matured. Pemberton gives an example: "Formed and welded metallic liners often result in stress concentrations that can't be ignored but are necessary for performance or manufacturability. Our solution was to add a small amount of carbon fiber to critical areas — like controlling build up at the bosses or adding hoop winds in the weld zones — to reduce strains, mitigate risk of fracture and ensure the fatigue life of the tank."

Because fastener holes can't be drilled in the pressure vessel itself, tanks are typically attached to the spacecraft by means of a *skirt*, which is bonded to the tank and then mechanically fastened to the spacecraft. "We needed a very stiff, lightweight means of attachment while meeting the overall tank assembly weight of 100 lb [45 kg], plus the skirt transmits all of the weight and loads of the tank to the satellite," says Pemberton.

... and a miniskirt

Composites enabled Cobham's skirt design for several reasons. Pemberton explains: "First, the skirt must match the stiffness of the external part of the tank. This would have been much more difficult to achieve in aluminum or titanium than with a tailored composite layup, especially with mass constraints. Also, the ability to lay the skirt up in pieces enabled almost any shape." A conventional tank skirt would be a straight barrel of a constant diameter, but Cobham devised a novel *tapered* section. Pemberton says, "Although it complicated design and fabrication, it provided an elegant solution to the mass, space and volume requirements. Because we could control the geometry of the skirt, it made the geometry of the spacecraft simpler, which is definitely what you want in terms of cost and schedule for the program as a whole."

Unidirectional prepreg was used to meet stiffness-to-weight requirements, but it was difficult to drape and form to the tapered section without wrinkling. The skirt layup was symmetrical and quasi-isotropic, varying from 48 plies at the bolt inserts to 24 plies at the bonded interface with the tank and required precise placement of roughly 1,200 individual pieces. "The pieces had to bend around the circumference and lean into the taper," Pemberton explains. "We used hand calculations and experience to develop the necessary ply shapes that prevented wrinkling and minimized distortion." Vacuum debulks, used after the first and third plies and a minimum of once every 12 plies thereafter, also helped.

"Composites also enabled us to tailor the modulus of the skirt in the hoop direction," says Pemberton, "so that it was enough to handle the tank pressurization loads and act like a belt but *not* so much that it crushed the tank."

Source: Cobham Life Support

Complex skirt carefully designed

The carbon fiber/epoxy skirt layup required roughly 1200 individual prepreg pieces to achieve its final complex shape. The photo at right shows templates used to cut plies for the skirt.

Source: Cobham Life Support

Tailored to optimize performance

The winding was tailored to optimize stresses and achieve required burst strength without adding unnecessary material. Here, winding begins with low-angle helical courses.

Grande adds, "That flexibility to constrain the modulus in one direction but not in the other helped us achieve the design we needed."

Tailorability also ensured that the tank met a key launch requirement: the natural frequencies of the assemblies must not contribute to spacecraft vibration. "This became an area for composites to shine," notes Estes, "because there was a change in the vibration requirements late in the game, which significantly increased the minimum natural frequency required. Such a design change with aluminum or titanium would have required scrapping the already developed tooling and starting over. But with composites, the change was met by adjusting thickness and layup." Thus, the massive change made a minimal impact. "We were able to beat the program schedule and meet cost and weight requirements as well," Pemberton recalls.

Intelligent analysis

According to Grande, one of Cobham's major achievements was that there was never a huge redesign or breakdown in progress. This was due, in part, to their development philosophy. "We chose to introduce novel solutions in the *design*, not the materials and processes," he explains, "but we are also very efficient in computer-aided engineering." Cobham starts with closed-form computer-aided calculations, or "hand calcs," because, says Grande, "Finite element analysis [FEA] is only as good as the data fed into it. This avoids easy mistakes and enables us to start with sound fundamentals in our loads, geometries and boundary conditions." Pemberton adds, "We then compare the hand calcs to the FEA. This is a key step that many companies overlook but there must be good correlation here in order to achieve overall efficiency in the design process."

Cobham also streamlines the statistical approach to developing material properties, putting strain gauges on pieces as early as possible and throughout development so computer models are updated with real properties and are continuously verified as the design progresses. Grande summarizes, "In the end, we cut the number of required destructive tests by almost half, saving months of time and roughly $500,000."

Estes credits one more factor: "Cobham is kind of unique in that the guy doing analysis one day will hand lay a skirt part the next day and apply a strain gauge and run a stress/strain test the next. Thus, the folks doing the design ... see the connection between manufacturing, material properties and structural performance," he says. "This improves the analysis and keeps them focused on what's critical."

Future fuel tanks

Validated via vibration and nondestructive burst-proof testing, the tank has been integrated into the GPM Core for launch in 2014. "By using this ... demiseable design," says Grande, "we increased the life from five to seven and maybe even 10 years, possibly doubling the amount of data collected per investment into the vehicle." ■

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