Our 2017 “State of the Industry” Report

Better Ballistic Materials

Composites in Consumer Electronics

January/February 2017

Composites Manufacturing
The Official Magazine of the American Composites Manufacturers Association

ACMA

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An engineer in the U.S. Army Research Laboratory’s Composites Processing Laboratory inspects a mild-heat fixture for processing of thermoplastic components, including ballistic materials. Photo Credit: U.S. Army Research Laboratory
Setting New Year’s Resolutions for Your Company – and ACMA

Happy New Year, and welcome to 2017! Our current business environment continues to be positive, and early indicators point to another good year for our industry.

Most of us set some type of personal or business-related New Year’s resolution. This is a good time to revisit those resolutions and ensure we have the right focus and alignment in place to be successful.

Every year at Crane Composites, we put our business plan in place incorporating our best thinking on our markets, growth opportunities and operational plans, all of which present opportunities and challenges for the coming months. In addition, we identify two to three strategic items – which could be considered resolutions – that would be a breakthrough in our business. The staff at Crane Composites get very clear and specific about what we want to accomplish, then put plans and a team in place to aggressively pursue those goals.

This focused effort is not only about accomplishing our 2017 business plan, but about setting ourselves up for the future. It is important to understand that trying to do too many things takes away from our resources and focus, which greatly reduces our probability for success. Getting your teams aligned around the resolutions that are most critical to your company will make a difference in your business.

Similarly, the ACMA team is focused on helping your business succeed by providing resources that help you position for the future. Our association continues to bring value to its membership by representing us collectively in a way that would be expensive and time consuming to do as individual businesses. The key to sustained success is your involvement in identifying those areas that would benefit you the most. I encourage you to have a voice in how we collectively address our industry’s opportunities! If you’ve not been involved before, consider it one of your New Year’s resolutions for 2017.

Thank you for your support and participation. You make a difference, and together we will continue to see our industry grow and prosper – this year and in the decades to come.

Jeff Craney
Crane Composites
ACMA Chairman of the Board
jcraney@cranecomposites.com
Global Company with Regional Focus

Polynt Composites is a leading producer of unsaturated polyester resins, gel coats, vinyl esters and other derivatives for the composites industry.

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The unique advantages of pultruded fiber reinforced polymer composites have enabled them to penetrate markets where other materials could not meet the design or end-use requirements efficiently. For high-volume applications, it is tough to beat the economics of the pultrusion process.

Pultrusion is a manufacturing process for producing continuous lengths of FRP structural shapes with constant cross-sections. Raw materials used in pultrusion include a liquid resin formulation, flexible textile reinforcing fibers and a polymer surfacing veil. In general, the pultrusion process involves pulling these raw materials – rather than pushing, as is the case in extrusion – through a heated steel forming die using a continuous pulling device. The reinforcement materials are in continuous forms such as rolls of continuous filament mats (CFM) or doffs (hollow spools) of fiberglass roving.

As the reinforcements are saturated with the resin mixture in a resin bath (“wet-out”), they are shaped by a preformer and pulled through a heated die. The cure of the resin is initiated by the heat from the die, setting off a catalytic reaction that results in a rigid, cured profile corresponding to the shape of the die cavity.

The pultrusion process can vary, ranging from a caterpillar puller (counter-rotating belt drives) to a reciprocating puller. However, the basic pultrusion process is described below and follows the flow shown in Figure 1 on page 6.

Starting from the tail end of the pultrusion line, roving racks and CFM creels hold the fiber reinforcements, which are delivered in wide rolls that are pre-slit to prescribed widths. The CFM is continuously pulled off the roll, similar to pulling paper towels. These creels can also hold other rolled goods such as stitched mats or tows of carbon fiber. The creels essentially stage the reinforcements for subsequent feeding into guide plates.

The guide plates precisely position the unrolled mats and rovings before entering the resin bath, which wets-out the reinforcements with a liquid resin formulation. The resin formulation generally includes a base resin, fillers, catalysts, pigments, wetting agents and an internal mold release.

The interior of the resin bath is carefully designed to optimize the wet-out of the reinforcements. Wet-out can be further optimized by separating the reinforcements as they are submerged in the bath. The resin bath is replenished with the resin formulation as the wetted reinforcement draws from the bath.

The John D. Tickle Bridge on the University of Tennessee’s campus, named after the chairman of Strongwell and an industrial engineering alumnus of the university, is made from pultruded FRP structural components, including beams, grating and an interlocking decking system.
exiting the resin bath, the unrolled resin-saturated reinforcements are oriented in flat sheets before they enter the preformer.

The preformer is where the flat layers of reinforcements (typically CFM) and roving are formed into a shape that is as close to the die cavity as possible. The preformer is an array of tooling that gently shapes the materials prior to entering the die. The process is comparable to forming rolled aluminum into a rain gutter. The preformer is the step of the process that can make or break the robustness of the pultrusion process. Ideally, the preformer should continuously and consistently form the wetted reinforcements for weeks of processing without human intervention.

As an alternative to a resin bath and preformer, some pultruders use resin injection. Typically, the reinforcements are formed dry and enter a closed cavity where resin is injected. Like the preformer, once formed and adequately saturated with resin, the wetted reinforcement enters the heated die.

The heated die is the final forming step. The preformer will form the wetted reinforcement slightly thicker than the die cavity, and the die will squeeze the last bit of resin, compacting the reinforcement package to its final thickness. Pultrusion dies are usually surface hardened via nitriding or chrome plating to resist the abrasion of the reinforcements and fillers. The heated die activates the thermoset reaction, and the composite is cured as it progresses through the die. The internal release agent in the resin formula helps prevent the resin from adhering to the die surface.

The curing of the resin is usually the limiting parameter for the pultrusion line speed. Very thick parts might only run three inches per minute, where thinner parts might go 100 inches per minute or more. The degree of cure of the part must be verified through testing. Poorly cured parts offer reduced mechanical properties, corrosion resistance and elevated temperature properties.

On exiting the die, the cured profile is very hot – typically 300 F to 400 F – from the die heat and the resin exothermic reaction. Parts must be cooled before

**Figure 1: Typical layout of a PULSTAR® pultrusion machine from Strongwell.**

Pultruded parts today can be much larger and more complex, utilizing a wide range of resin systems, reinforcements and processing methods.
entering the polyurethane grippers of the puller. If a part is too hot when it enters the grippers, the part or the polyurethane grippers can be damaged. The cooling down process can be accomplished by extending the distance between the die and the puller (natural convection cooling) or by forcing air or water on the part between the die and the puller.

The cured profile is gripped by the puller. Pultruders typically use two continuous pulling systems; one that is a caterpillar counter-rotating type and the other a hand-to-hand reciprocating type. The puller is what makes the processes continuous. It is the same puller that overcomes the resistance of the drag of the dry reinforcements going through guides; the viscous forces of the resin being metered in the resin pan, preformer and die; the adhesive forces in the die and the force needed to push the traveling cut-off saw.

Depending on the part size, the pull forces can be as low as 200 pounds to as high as 100,000 pounds.

The final step in the pultrusion process is to cut the part to length without stopping the line. The traveling cut-off saw accomplishes this by moving at the same speed as the part as it makes the cross cut. Once the cut is made, the traveling cut-off saw goes to its “home” position before the next cut is triggered.

The pultrusion processing parameters, such as die zone temperatures, line speed, part cut length and gripper forces, are typically set and changed at a control panel or touch screen. Each part will have unique processing requirements that can be readily modified by the machine operator.

One of the most familiar pultruded parts is the rails of fiberglass ladders. This relatively simple shape has been manufactured using pultrusion since 1959. Pultruded parts today can be much larger and more complex, utilizing a wide range of resin systems, reinforcements and processing methods.

Learn More About Pultrusion
The first ever North American Pultrusion Conference will take place April 4-5, 2017, in Atlanta. The event, co-produced by ACMA and the European Pultrusion Technology Association, will bring together leaders in the composites industry, customers, OEMs and suppliers to discuss the latest worldwide opportunities for pultrusion. For more information and to sign up, visit www.acmanet.org/pultrusion.
Training Program Takes Flight

Utah’s aerospace and defense industry is growing, with nearly 950 companies employing more than 31,000 people in the sector in 2015. That’s great news for Utah, but attracting a qualified workforce to employers ranging from aerospace giant Boeing to parts suppliers such as Janicki Industries can be challenging considering the state’s unemployment rate averaged around 3.5 percent in the past year.

In 2015, a coalition of government, education and industry partners launched the Utah Aerospace Pathways program to help solve the dilemma. Last spring, 41 high school students from two school districts in Utah completed the pilot program and earned certificates in aerospace manufacturing, providing a direct and accelerated path to employment in the aerospace and defense industry.

“The point is to provide not just a job, but a career path,” says Ben Hart, managing director of the Utah Governor’s Office of Economic Development, which helped spearhead the program. It’s a career path with composites and advanced materials at its core. “Composites are an important part of the Utah economy,” says Hart. “Why wouldn’t we try to do everything possible to line up our K through 12, post-secondary and higher education with future opportunities?”

Hart says that industry was the catalyst in getting the Utah Aerospace Pathways program off the ground. “That’s a critical component in any workforce program,” he says. “Industry must be willing to not just be a consumer, but help produce really good workforce programs.”

In the spring of 2015, Boeing teamed up with other aerospace companies and approached the Governor’s Office of Economic Development seeking a workforce solution. Hart’s team quickly pulled in other government and education partners. They worked diligently for six months before launching the Utah Aerospace Pathways program in September 2015.

The program, which is open to high school juniors and seniors, utilizes a three-pronged approach. During the first semester, students take a 60-hour course at their high schools introducing them to manufacturing basics. The following semester, they enroll in a 48-hour course on aerospace composites and other advanced materials at either Davis Applied Technology College (DATC) in Kaysville, Utah, or Salt Lake Community College. At the same time, students participate in a 48-hour, paid internship at one of the industry partner’s facilities. These include...
Albany Engineered Composites, Boeing, Hexcel, Hill Air Force Base, Janicki Industries and Orbital ATK.

“You’ve got to have the three-legged stool, with high schools, vocational schools and industry working together,” says Kimberlee Carlile, pathways manager for the Governor’s Office of Economic Development. “Students get not only the classroom experience, but hands-on training from vocational schools and industry experience as well.”

The composite materials technology course offered by DATC requires students to work in the advanced composites laboratory. “At the high school, they are mostly getting theory, but here they roll up their sleeves and work in the lab,” says Ginger Chinn, vice president of external engagement and economic development at DATC. Students are introduced to hand layup and some machine tooling. They complete a final project, such as construction of a skateboard. They also build a miniature bridge, then complete a stress test on it and break the bridge.

Salt Lake Community College offers a similar course.

Internship experiences vary by company. At Albany Engineered Composites, students learn by watching composites technicians and participating in supervised setup of jobs. They also complete an onsite project using scrap materials, such as fabricating a cell phone stand using hand layup.

“They actually follow the same processes and techniques we use on aerospace components to create their project,” says Pam Burke, director of human resources at Albany Engineered Composites in Salt Lake City. “We also stress the criticality of documentation – how they have to follow standardized work procedures and adhere to documentation. This is no longer a high school project; they are working side-by-side with full-time employees.”

When students complete their certificate in aerospace manufacturing, they are guaranteed a job interview if they apply for full-time employment with any of the industry partners. “Students have completed an internship, making relationships and connections with industry partners,” says Carlile.

All of the 41 students in the first Utah Aerospace Pathways cohort successfully earned their certification. As of October 2016, 15 of them were employed with one of the industry partners. Some students were juniors, so they aren’t yet eligible for employment. Others left for religious missions upon high school graduation. In addition, some students opted to continue their education and enrolled in the full composite program at DATC or Salt Lake Community College.

Albany Engineered Composites had eight interns last year. It hired four of them, plus one student who interned at another company, as entry level composite technicians. While interns don’t increase production at the company, Burke says the value of the Utah Aerospace Pathways program to industry is undeniable.

“My trainers who were engaged with the interns were energized and impressed by their intelligence and passion,” she says. “Being onsite gave the students a chance to get a feel for what manufacturing is really about today and to ‘try before they buy.’ Now they are making an educated decision about joining the composites industry.” Hopefully, that will lead to less employee turnover and associated costs.

The pilot program was such a hit that it was expanded in the fall of 2016. The two original school districts – Granite and Davis – continue to participate. In addition, Utah Aerospace Pathways has spread to Ogden and Iron County School Districts. The program has doubled the number of students it serves to approximately 80. “Every school district in the state wanted to do this, but there’s always the quality component to consider,” says Hart. “It takes time, and we want to make sure we grow this program the right way.”

Ultimately, he would like to see all of Utah’s students exposed to composites training, starting with targeted outreach events to early elementary students. “We talk about the woodshops of yesteryear,” says Hart. “Our dream is to have composite labs in high schools across the state, then stack that with training at our vocational schools and into higher education. Composites are the future.”

For the program’s industry partners, future success hinges on collaboration. They’ve committed to the Utah Aerospace Pathways program because they are stronger together than apart. “It’s not about beating the competition. Many of us are supplying to the same OEMs, and we want them to be successful,” says Burke. “This is a collaboration of industry partners saying, ‘Let’s solve this workforce problem together so that we all win.’”

Susan Keen Flynn is managing editor of Composites Manufacturing magazine. Email comments to sflynn@keenconcepts.net.
When it opens this summer, the 186-foot Halls River Bridge in Homosassa, Fla., north of Tampa will likely have more composite elements than any vehicular bridge in the United States. While each of the composite technologies has been used in other projects nationally, the bridge, which will replace one built in 1954, will feature composites in its pilings, deck, retaining walls, abutments and traffic rails.

“There are some pedestrian bridges, but to our knowledge I don’t think there’s another vehicular bridge that’s used composites in every element to this extent,” says Steven Nolan, P.E., senior structures design engineer with the Florida Department of Transportation’s State Structures Design Office in Tallahassee. He cites pioneering work by the University of Miami’s College of Engineering, which built a pedestrian bridge on campus that extensively used composites and was a collaborator on the Halls River Bridge design.

The bridge replacement project began in 2012 when engineers at the FDOT chose the Halls River Bridge as a demonstration site for the state’s first bridge built with Hillman Composite Beams® by HCB Inc., Alpharetta, Ga. (HCBs were described by inventor

John Hillman in a 2016 *Composites Manufacturing* article, “Making Inroads in Infrastructure,” as FRP boxes with a steel tension tie in the bottom flange resisting the thrust from a concrete arch inside the box. The FRP outer shell provides shear strength, the concrete arch offers compressive strength and the steel reinforcement running longitudinally provides tension capacity.)

While the project began with a focus on HCBs, as planning progressed the FDOT engineers saw opportunities to create proof-of-concept applications for other composite technologies, too. “Ultimately, we replaced every reinforced concrete element in the project with some form of composite material or hybrid – either carbon pre-stressed reinforced concrete, GFRP-reinforced concrete, or, in the case of the HCBs, a composite shell over a steel-reinforced concrete core,” says Nolan.

The FDOT opted for composites primarily because of the high costs of maintaining traditional steel-reinforced bridge elements in the state’s saltwater and wetland environments.

“The majority of long-term maintenance costs on our bridges are the result of degradation of the substructure, predominantly our pilings,” says Nolan. “We spend a major portion of our bridge maintenance budget on rehabilitating piles on bridges over saltwater crossings.” Rehabilitation includes replacement, repair, pile jackets and cathodic protection – all of which are expensive and require working within the body of water.

“Our goal is to get in and get out

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**Composite Elements in Bridges Across North America**

John Busel, vice president of ACMA’s Composites Growth Initiative, outlined the number of bridges utilizing composites in a 2016 presentation to the Rhode Island Department of Transportation. There are currently more than 480 bridges in the U.S. and Canada with composite elements, including the following:

- 388 decks (including panel system, superstructure and rebar/grid)
- 63 girder/beams
- 50 parapets, barriers, enclosures, sidewalks
- 20 tendon cables
- 19 panels
- 17 carbon fiber/glass concrete filled arches
- 14 pier (column) fendering systems
- 9 FRP/glulam beams
- 7 abutments/footing
- 4 piling/columns
Composites look like they will give us the capability to not have to worry about continued maintenance of our substructure within the practical service years of the bridge,” says Nolan.

The Halls River Bridge piles will be constructed from CFRP pre-stressed concrete. Piles are traditionally pre-stressed with high-strength steel strands and spiral reinforcing to prevent cracking during pile driving. Cracks invariably still occur, as does long-term chloride ion diffusion from saltwater. “By using composites, we don’t have to worry about corrosion or degradation of the surrounding concrete if chlorides do penetrate,” says Nolan.

The piles will be manufactured by Gate Precast in Jacksonville, with Carbon Fiber Composite Cable (CFCC”) supplied by Tokyo Rope. A 15-millimeter diameter, seven-cord CFCC with six carbon fiber cords helically wound around a central straight cord will be used to pre-stress the piles longitudinally. A total of twelve CFCC strands will also be distributed along the perimeter of the rectangular pile, and a single 5-millimeter diameter CFCC cord will be helically wound around the length of the pile to provide spiral containment.

Each of the bridge’s five spans will be built with nine, 36-foot HCBs fabricated by authorized manufacturer Kenway Corporation in Augusta, Maine. According to Nolan, ordinary bridge beams are typically either concrete, pre-stressed concrete or steel. “We’re using a hybrid composite beam that contains all three – steel strand, concrete arch and composite shell,” he says. The GFRP shell will protect the beams from saltwater splash and spray, including from jet skis and boats. The deck will also include GFRP reinforcing bar rather than steel to further eliminate potential chloride-induced corrosion from the underside.

In addition, GFRP will be used in the bridge’s abutments, concrete caps, traffic railings, approach slabs and sheet pile retaining walls. “GFRP is used in almost everything but the piles and the beams,” Nolan notes. The sheet piles have GRFP transverse reinforcement around the perimeter and either a carbon or steel pre-stressed concrete core.

One of the main challenges of building a bridge with composites is a lack of familiarity with composites in the design community. In addition, efficient composite design tools aren’t readily available. Consequently, FDOT’s State Structures Design Office provided the regional FDOT office in Tampa with standards for the project’s piles, sheet piles, approach slab, traffic railing and gravity wall. Nolan says these standards can be used on future projects.

The Halls River Bridge is designed for a 75-year lifespan, as required by code, but is expected to last much longer. “The qualification of the durability is still an ongoing science, but we would expect that we would not have any problems with this bridge within 100 years,” says Nolan. The first phase of the bridge will open in June – just in time for Florida’s scalloping season.

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“Composites look like they will give us the capability to not have to worry about continued maintenance of our substructure within the practical service years of the bridge.”

–Steven Nolan, P.E., Florida DOT

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ACMA Advocates for Infrastructure

From February 7-9, 2017, ACMA and its members will continue to advocate for the increased use of FRP composites in infrastructure applications by meeting with staffers from various members of Congress and the National Institute of Standards and Technology.

To learn more, check out “Inside ACMA” on p. 35.
Improving Pets’ Lives by Leaps and Bounds

You’ve probably seen dogs moving around on three legs, but you may be unaware of the ramifications as they age. They often develop arthritis in their hips and other joints, which can deplete their energy, leave them house-bound and affect their well-being.

“I’ve witnessed animals saved through amputations only to see them struggle to lead normal lives,” says Bill Bickley, a licensed orthotist and prosthetist. “I thought the use of CFRP prosthetic limbs like those of Olympic athletes could advance animal prosthetics.”

In 2013, Bickley founded Pet Artificial Limbs & Supports (PALS) Houston. While others were offering animal prosthetics, there was no equivalent to the CFRP blades Bickley had in mind. “CFRP offered improved strength and flexibility that would provide freedom and put more life and bounce into the steps of our four-legged friends,” says Bickley.

His search for expertise to integrate CFRP into the compound curves of prosthetic blades led him to Hans deBot of deBotech, Inc., whose experience developing CFRP parts for aerospace, marine, motorsports and even Olympic bobsleds impressed Bickley. deBot wholeheartedly agreed to help. “I am a dog lover myself, and my family currently owns three dogs,” he says. “I understand that there is no better friend.”

Bickley and deBot had little information and no data on the load requirements for the initial design of a CFRP animal prosthetic. A few preliminary requirements were clear. The length of the blade needed to make up the distance between the residual limb and the ground. The blade also needed to compensate for the animal walking, then running. In addition, the design required varied stiffness and flexure rates from the top to bottom of the blade, with higher rigidity and strength at the mounting position for robust, weight-bearing performance and increasing flexure rates down the length of the blade to mimic the animal’s joint. The final result needed to be flexible when the animal was walking and provide an immediate input of power and energy absorption when the animal ran.

Bickley and deBot designed a prosthetic with a hollow polypropylene cup equipped with an aluminum mounting plate that slips over the residual limb and is held in place with Velcro straps. The CFRP blade is then affixed to the mounting plate with screws. The lower end of the blade attaches at the bottom to a plastic “paw” with a rockered bottom covered with a non-slip material such as rubber to form the sole. The paw (which is subject to wear) is replaceable, while the CFRP blade is designed to last the animal’s lifetime.

One of Bickley’s early patients was Leo, a miniature collie whose front leg was lost to amputation and whose owner was determined to see him run again. Bickley obtained a CFRP limb from an overseas supplier and trimmed the piece to fit Leo. No one was sure how Leo would respond when the prosthesis was applied. “Animals are not picky, they just notice that they have their leg back,” says Bickley. Leo took off running, and the CFRP piece snapped. This particular construction didn’t work, so Bickley was back to the drawing board.

Realizing he needed a custom solution using woven CFRP, Bickley forwarded an aluminum prototype to deBot, who produced a group of CFRP samples for Bickley, which worked for Leo right out of the gate. Leo’s owner was thrilled. “The owner has a new puppy, and the prosthetic is the only thing that enables Leo to keep up with his young friend,” says deBot.

The success of the CFRP prosthesis lies in the high strength and stiffness-to-weight ratios and good fatigue behavior, which better simulate what the arm or leg does for the animal. Reinforcing the layup where the prosthesis will be mounted and varying the stiffness throughout the length accommodates changes in the animal’s activity. “You could not achieve the same mechanics from steel or other materials,” says deBot.

With her CFRP prosthetic, 14-year-old Bella can walk and play in comfort. Her prosthetic limb behaves like a spring, flexing as much as ¾ to one inch per step.
Evolving Composites Skills

How do you make composites fabrication better, faster, and less costly? The merger of traditional processing technology with emerging digital technologies is one realization of that goal. The permeation of digital technology into the composites industry has propelled a paradigm shift in the types of skills relevant to today's employers. The ability to produce a 3D digital model of a product and direct machine a mold has eliminated two costly steps in the process - hand fabricating a pattern and then constructing a composites tool to produce the first part. By using easily machinable materials a CNC router can quickly and accurately create a mold capable of producing production parts. When more parts are needed to meet volume requirements, a master plug can be pulled from the direct machine tool, and duplicate composite molds produced as required. This technological shift speaks to a recognition of the skills required to work in the new digital medium. Traditional composites aptitude is being augmented by digital modeling and CNC operational skills. A well rounded composites technician still requires mastery of the fundamental molding processes and an understanding of materials systems, but the addition of digital technology creates the vision for the next level of possibilities – Digital modeling, CNC tooling, 3D printing and low cost automation of production processes are the future of more efficient and profitable production.

The transition from an emphasis on handcraft skills to proficiency with the digital toolbox is in progress, and training programs like the ones at IYRS in Rhode Island are leading the charge. The development of technicians with this evolutionary skillset will drive composites into the future.

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Day in the Life of an IYRS Composites Technology Student

Jan 27, 2017

8:45am Introduction to computer-aided design fundamentals
10:10am Meet w/ instructor to go over proposed wind turbine blade design patterns
11:00am ACMA CCT® Certification exam prep (open molding this month, vacuum infusion next month)
noon take down the waterfront for lunch with John and Kelcey
1:00pm get into our teams and finish building our vacuum bag exercise (testing it cut tomorrow!!!)
2:00pm Review notes from CNC and CAD/CAM principles course
3:50pm meet with team to review project timeline & budget proposal
4:45pm clean up shop, start sorting through job opportunities and target companies for work
The prosthetic limb is made from aerospace-grade, ISO-certified prepreg carbon fiber with epoxy resin from Cytec Solvay Group. “Prepreg is tailor able to the design and provides us with a more consistent outcome,” notes deBot. Both unidirectional and multidirectional fiber orientations are deployed, with a combination of long-axis fibers at 0 and 90 degrees along the length of the member. “Each design varies the fiber orientation and number of layers to handle the size of the animal, front versus rear leg and specifics of the medical case,” says deBot. “Bill Bickley has gotten to be quite an expert in knowing which layup type to select based on his patients’ needs.”

The material is layed up, then vacuum-bagged and placed in an autoclave to cure. After demolding the blade, deBot trims the part and sends it to Bickley. Since they are still in the development stage, Bickley provides feedback, requesting increased stiffness or more flexibility in certain areas of the blade. Their most challenging case to date was a double front amputee Chihuahua named Cowboy. After receiving two carefully aligned blades, Cowboy is off and running in his hometown of Las Vegas. “Each animal is different and we are still in the trial and error phase, but we have been able to successfully accommodate each patient,” says deBot.

To date, Bickley has worked with surgical centers, zoos and veterinary teaching hospitals. The cost of an average prosthetic dog leg is about $1,500. This may sound expensive, says Bickley, but pet owners should consider the cost a wise investment compared with the potential cost of later surgeries and other treatments that arise in a pet with three legs.

For deBot, the reward is more emotional than financial. “Watching Maggie – a big black lab who wasn’t walking, eating or moving – put on her prosthesis, take off running and pull her owner by the leash was very gratifying,” he says. “We are making a difference in these animals’ lives.”

Patrice Aylward is a freelance writer in Cleveland. Email comments to paylward@aol.com.

Cowboy, a double front amputee Chihuahua, posed unique challenges in the development of his CFRP prostheses because of the need to replace two missing limbs and account for his light weight.
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Composites manufacturers are continually looking for ways to enhance the performance of materials, making them thinner, lighter and stronger. But producers of ballistic composites have a much greater incentive for improvement than most: the material changes they make can literally save lives.

The most common types of composite ballistic materials used today are para-aramids (aromatic polyamides) such as Kevlar® and Twaron® and the newer high-molecular weight polyethylene (HMWPE) or ultra-high-molecular weight polyethylene (UHMWPE) such as Dyneema® and Spectra®. Military and police forces, the main customers for ballistic composites, have used one or both types for helmets, body armor, vests and shields and for armor components on tanks, helicopters, planes and other vehicles.

Ballistic composites provide significant performance enhancement and weight reduction over metal ballistic materials in such applications. “When you replace metal with a non-metallic system like a standard polymer matrix composite material you’re significantly lessening the likelihood of degradation due to corrosion in extreme environments,” says Steve Taulbee, general engineer in the Office of the Director for the Weapons and Materials Research Directorate at the U.S. Army Research Laboratory at Aberdeen, Proving Ground, Md.
The Evolution of Military Ballistics

The U.S. Army started investigating the potential of composite materials for ballistic applications (specifically Kevlar vests) at the end of the Vietnam War. In 1989, the Army fielded its first composite helmet in combat in Panama, made from a Kevlar fiber hardened by a thermoset resin matrix. The most recent iteration is the enhanced combat helmet (ECH), made with UHMWPE. “It improved ballistic protection by 35 percent over any and all of the previous generations of the Kevlar helmet,” says Taulbee.

The Army is currently researching the use of UHMWPEs to reduce the weight of next-generation military aircraft, pursuing 3-D weaving with several industry partners, including Albany Engineered Composites and T.E.A.M. Inc.

With military aircraft, there is a lot of pressure to reduce the weight of the armor without compromising protection, says Nick Baird, director of sales and marketing at Permali Gloucester Ltd. The company uses aramids, glass fibers and UHMWPEs to create ballistic protection for helicopters like the CH-47 Chinook and the AW101 Merlin. The materials have to resist vibration and crash loads and meet flammability specifications as well.

Permali is investing heavily in the development of molded composite structures to provide mine and blast protection for vehicles. “We have shown that the right composite solution outperforms steel by resisting higher blast loads, by having lower dynamic deflection and by exhibiting ‘graceful degradation,’” says Baird. “Composites show very progressive behavior as you increase the blast loading, whereas steel fabrications tend to fail suddenly and catastrophically as you exceed their threshold.”

In one case, Permali replaced a steel roof on a vehicle with a stronger, stiffer composite roof, providing a rigid and stable platform for a roof-mounted remote weapon station.

Baird says military forces are expanding the use of ballistic composites. “Up until maybe the early 2000s only battlefield platforms – main battle tanks, armored fighting vehicles and attack helicopters – were armored,” he says. “Now as we face increased threats from terrorism and engage in asymmetric warfare, the battlefield is not so well defined. There is less willingness amongst the general public to accept casualties, which creates political pressure.” Baird adds that it’s now commonplace for logistic and patrol vehicles, transport helicopters and even naval ships to be fitted with protection against small arms fire and improvised explosive devices (IEDs).

In order to optimize and better integrate composite materials for these applications, armor manufacturers have been working with composites companies earlier in the design stage of a project, he adds.

Design Variations

Honeywell introduced the first generation of its UHMWPE spun ballistics fiber, Spectra Shield®, in 1989. Variations of the fiber have been used for vehicle protection, helmets, breast plates, personal shields and soft armor vests.

Spectra is generally based on a normal composite unidirectional fiber substrate. “What’s unique about our material in the unitape form is that unlike most composites, which are resin rich, ours is resin starved,” says Lori Wagner, Honeywell special projects leader. “That allows the fiber to work in its best condition, to be able to react to the high stream rates of the ballistic offense and respond without being constrained by resins. The fiber is actually the component that is stopping the bullet, so we want to pack as much fiber in as possible.” The resin’s role is to supply enough structure so that the fiber can respond.

Resin-starved structures are more delicate to handle during the manufacturing process. “There are a lot of extra steps that are taken because we need to have the fiber in a form that will..."
respond best to the bullet contact,” says Wagner. The final product, however, is a very robust system that can be handled just like any other type of composite.

Honeywell uses a variety of resins, including elastomers, polyurethanes, polyolefins and vinyl esters, with the choice dependent on the application. Helmets need resins that provide stiffness so the helmet will retain its shape. A vest, which should be supple and comfortable, requires a resin that isn’t hard or rigid. Much of Honeywell’s research and development goes into finding the right combination of resin, matrix system and lay up.

The design of ballistic materials presents challenges familiar to any composites manufacturer. Producers must assess the environment where the finished product will be used: operating temperature, chemical resistance, fire resistance and smoke and toxic fume emissions. They must consider structural requirements; for example, will a composite armor panel need to support the weight of other attached equipment? How will they attach composite armor to a platform? How will they avoid ballistic weaknesses at panel joins and corners?

Ballistic composites must also provide protection against a wide variety of threats. Vests may have to deflect bullets from many different types of guns, while armored vehicles must be able to withstand projectiles, roadside bombs and shells fired from tanks. Each type of threat interacts with composite materials in a different way.

“Different composite ballistic materials offer different trade-offs between these sometimes conflicting issues, so it is crucial to fully understand and appreciate the merits and performance of all the material choices available,” says Baird.

Taulbee notes that one of the biggest challenges has been coming up with composite panels that can provide the required levels of toughness, fracture resistance and ballistic protection without delaminating when struck by bullets.

Adapting New Technologies

Some military forces are experimenting with incorporating multifunctional ballistic materials into the protective equipment that soldiers wear. Conductive materials could someday monitor a soldier’s heart rate or streamline communications. “If you could build the antenna communications system directly into [a composite vest] it could have a much sleeker design and be much lighter weight,” says Wagner. Reducing the bulk of the gear that soldiers carry minimizes their profile so they are harder to target and reduces their risk of getting caught on any obstacles.

Companies are also investigating how nano-technology could enhance the ballistic properties of composite materials. “One of the most promising classes is graphene – a 2-D, carbon-based nanomaterial,” says Taulbee. Because the carbon layer is so thin – almost at the level of atoms – researchers can control and engineer its properties. He predicts that in the long term, ballistic materials made with graphene could be “10 times the strength of steel and 10 times lighter than steel.”

ANF Technologies has developed a patented process for dispersing aluminum oxide nanofibers – brand name Nafen™ – into various resin systems, including epoxies, polyurethanes and phenolic resins. Nanosilica, carbon nanotubes and some other nanomaterials can be difficult to disperse because they have a tendency to agglomerate, according to Tim Ferland, ANF Technologies’ business development manager. Nafen is different, however, because it is not produced through high-energy electrospinning, but grown off the surface of molten aluminum.

“That creates some very unique features,” says Ferland. “We have a true, solid nanowire. It’s straight, not curved or crooked or
difficult to untangle like carbon nanotubes, and it’s not spherical like nanosilica. So, it has a very high aspect ratio and a very high surface area. Being aluminum oxide, it has very high strength intrinsically; it’s one of the hardest substances next to diamonds.” Dispersing the aluminum oxide nanofibers into resin systems improves the systems’ mechanical properties. Ferland says that composites produced using Nafen have demonstrated increases in interlaminar shear strength, flexural toughness and impact toughness. “A lot of companies are putting macro fibers into their resins trying to use them as a reinforcement. What that does is create more filler in the resin system but the resin itself still isn’t improved. . . . With nanomaterials you’re actually changing the chemical structure of the resin and making the resin tougher. So, if you hit something and it starts to crack, the crack propagation is stopped much faster because on a molecular scale this energy is being absorbed by this crisscross mesh. It’s like a 3-D mesh of nanofibers mixed through the system.”

The Alchemie Group uses Nafen nanofibers in epoxy resins that are combined with its AuTx™ yarns/textiles to produce armor composites. According to CEO Haslen Back, the company was able to reduce the weight of a vest fragmentation pack of an improved outer tactical vest for the U.S. Department of Defense by 27 percent using AuTx textiles. The company is now working on reducing military helmet weight with AuTx composites.

Purdue University testing “confirmed that AuTx has twice the toughness (dynamic strength) of para-aramid fibers like Kevlar KM2+ and Twaron 50F1000,” says Back. Armor composite samples with Nafen particles showed a 20 to 40 percent improvement in performance over para-aramid armor composites using velocity-50 percent (V50) ballistics testing. (In V50 test, bullets are fired at higher and higher velocities until they start penetrating. The V50 rating comes from the point at which 50 percent of the bullets penetrate and 50 percent do not.)

Back admits that AuTx is more expensive than a HMWPE like Dyneema and that HMWPE laminates are better at stopping some types of bullets at certain temperatures. But AuTx performs well under a wider range of operating temperatures (~40 to 248 F) and has a very high modulus while retaining toughness. It’s also possible to vary the resin content of its epoxy system, so the front of an armor ceramic-faced composite can receive more resin reinforcement than the back. That variation in resin is not possible with HMWPEs, according to Back.

He says that some ballistics manufacturers are using a combination of composites like AuTx with HMWPEs either through interweaving or within the laminate system to provide armor with the advantages of both materials.

Creating New Opportunities

Composite ballistics have found new markets as organizations become increasingly concerned about threats from terrorists and active shooters.

Southern States LLC is manufacturing ballistic composite protective walls and barriers (Ballisti-Wall and Ballisti-Cover) to help defend and camouflage utility substations and other critical facilities and equipment. PolyOne Advanced Composites produced the continuous fiberglass composite panels (branded Glasforms) for this application. “We’ve developed a variety of ballistic-resistant products that all share a common attribute: very low weight for a high threat protection level,” says James Stephenson, general manager of Glasforms. The Glasforms materials, which are easy to install and transport, provide both high energy-absorbing properties for blast protection and ballistic protection for threats ranging from 9 mm handguns through 120 mm mortar rounds.

“Compared to traditional materials such as concrete and steel, advanced composites allow for faster and lower-cost installations for applications not previously served by these materials,” says Stephenson.

Interior design is another new market, according to Wagner. Some embassies are looking at lightweight, movable panels that can serve both as room partitions and also as shields for a first line of defense. People are also using ballistic composites for items like brief cases, clipboards and even whiteboards in classrooms. In an emergency, the whiteboards could be placed over doors or windows to provide some protection against someone trying to shoot into a classroom.

Ballistic composites have helped turn one entrepreneur’s ideas for an indestructible shelter for tornado zones into a reality. Wes Kouba, president of Buckeye Springs LLC, developed the concept for the Tornadopod after seeing the devastation wrought by twisters in Alabama and other southeast states.

The Tornadopod fits within a 5 x 5-foot space in a yard and can shelter up to six people. Almost half of the six-foot tall structure is buried in the ground, secured by 12,000 pounds of concrete. A 3.5-foot dome, comprised of a steel pipe safety cage and ballistic shield, sits above the surface. The dome shape prevents some debris from accumulating on top of the structure, but if debris does hinder the door from opening, occupants can release its hinges from the inside, providing another means of exiting.

To cover this dome, Kouba wanted a material that was lightweight, affordable and provided excellent ballistic performance. He investigated dozens of options, including a steel dome sprayed with ballistic fiber, but that proved to be too heavy. His search eventually led him to Innegra Technologies, which manufactures Innegra, a very high-modulus polypropylene (HMPP) fiber with good ballistic properties. Innegra is also hydrophobic, so it doesn’t easily absorb moisture.

Light weight was very important for the Tornadopod application. Innegra is already a light material, and the extrusion process used for its production makes it even lighter. (Kevlar weighs 1.44 grams per cubic centimeter, while Innegra weighs .84 grams per cubic centimeter.) Other materials that Kouba had previously tested required a laminate so thick (1¼ inch) that labor costs were astronomical. With fabric woven from Innegra fibers, however, the part was slightly under ¾-inch thick and 20 percent the weight of the other laminate.

The properties that Innegra brings to a composite depend on where the material is placed within the laminate. A client who wants a lighter part may use Innegra as a core material. “Added to a composite structure close to the surface of the laminate and it all but eliminates stress fractures,” says Russ Emanis, Innegra Technologies’ chief composites engineer.

The Tornadopod’s composite stack consists of the Innegra fiber layered with a number of other traditional ballistic
After modeling and testing various composite designs, Innegra developed a material that could pass the Federal Emergency Management Agency’s stringent tests for approved tornado structures. The Tornadopod’s dome was undented after it withstood the impact of a 16-pound, 2 x 4-foot piece of lumber fired at more than 100 mph.

Kouba staged other dramatic tests to demonstrate the strength and effectiveness of the Tornadopod’s composite ballistic shield. His team dropped a full-size SUV on it, first from a height of 20 feet and then from a height of 35 feet. (Kouba was inside the Tornadopod for the second drop). “The pod just flexed with it, absorbed the energy and literally pushed the SUV off the pod,” he says. “The Innegra absorbs the energy, flexes and comes back without breaking.”

No breaking. No shattering. Complete protection. That’s the ultimate goal of all ballistic composites. It’s a lofty one, but manufacturers and suppliers devise new materials and methods each day to provide greater protection.

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2017 State of the Industry Report

A look at five key areas in the composites industry.
Since 1960, the U.S. composites industry has grown 25 times, whereas the steel industry has only grown 1.5 times and the aluminum industry is three times larger, according to market research firm Lucintel. That’s good news for composites, but to understand the growth – and ensure it continues in the future – it’s important to dig deeper into the numbers and break down the industry into segments.

In this year’s annual State of the Industry report, Composites Manufacturing magazine asked several industry experts to share insight in key areas – glass fiber, carbon fiber, aerospace and automotive. We also got a report on the European market to highlight the global impact of composites.

The Glass Fiber Market
By Dr. Sanjay Mazumdar, CEO of Lucintel

In 2016, the U.S. composite materials market grew by 3.7 percent to reach $8 billion in value. It is expected to reach $10.6 billion by 2022, with a compound annual growth rate (CAGR) of 4.9 percent. Major drivers in the market include increased demand for lightweight and fuel-efficient vehicles, growth in new construction, upgrade of old infrastructures and increased demand for wind energy.

As more original equipment manufacturers utilize composites in various applications, the future of glass fiber composites looks promising. Across industries, end users are looking for products that offer better value for their money, superior quality and increased lifespans. In turn, the composites industry is shifting gears and investing in new R&D initiatives and attempting to capture business and applications previously considered out of reach.

Glass fiber – the predominantly used reinforcement – is expected to reach $9.3 billion worldwide by 2022, with a CAGR of 4.5 percent since 2016. The growth in construction and infrastructure development, increase in automotive production and development of water infrastructure and sewage systems are drivers in the glass fiber market. The global demand for clean energy and infrastructure upgrades also will help to boost glass fiber demand in the future.

On the supply side, Lucintel estimates an expansion or upgrade of existing facilities by at least 20 percent to meet glass fiber demand in the next two to three years. In 2016, the global glass fiber capacity was 11 billion pounds for composites, and the current rate of utilization is approximately 91 percent.

In recent years, there have been strategic shifts within glass fiber manufacturers to expand glass fiber operations in the U.S. and around world. Johns Manville, AGY, Chongqing Polycomp International Corporation (CPIC) and Jushi are setting up glass fiber units in North America and South America. European glass fiber manufacturers are also expanding their capacity to fill the vacuum that was created after imposing anti-dumping and anti-subsidy duties on Chinese manufacturers. LANXESS has invested $19.5 million to expand glass fiber plant capacity in Belgium, while Johns Manville has invested $65 million to expand glass fiber plant capacity in Slovakia.

In addition, there is a significant increase in glass fiber capacity in the Middle East by Chinese manufacturers. In 2013, Jushi established a plant capacity of 80,000 tons (176.3 million pounds) in Egypt and added another 80,000 tons in 2016. By 2017-2018, the total annual capacity of Jushi’s Egyptian site is planned to reach up to 200,000 tons (440.8 million pounds), whereas CPIC formed a joint venture with Abahsain Fiberglass ME (AFG) to build a plant with a capacity of 200,000 tons per year.

Apart from plant capacity expansion, numerous companies are developing advanced glass fibers, with a trend toward increased tensile strength, modulus and temperature resistance. In the wind energy market, increasing blade length requires the use of high-performance materials to increase stiffness and reduce weight. To address these challenges, Owens Corning, Jushi and AGY have launched high strength and stiffness glass fibers. For electronics, AGY has recently introduced S-3 HDI yarns to meet the need for low coefficient of thermal expansion and high modulus materials for integrated circuit package substrates.

To meet market demand for stronger materials and compete with carbon fiber and other materials, glass manufacturers are working to develop glass fiber with tensile strength two to three times higher than existing products. Applications such as wind blades, bicycle frames and various automotive and aerospace parts require high modulus to withstand bending and strain.

In conclusion, there will be significant future opportunities for GFRP composites. To capture future growth and profit from these opportunities, OEMs, Tier 1 suppliers and material suppliers need to work together, deploy the appropriate investments and resources, and develop new technologies to execute strategic objectives around light weight, low cost, composites repair and recycling.

Global Glass Fiber Demand and Capacity from 2011 to 2016

Source: Lucintel’s market report, “Growth Opportunities in the Global Glass Fiber Market”
The Aerospace Market
By Deepak Karthikeyan, Industry Manager – Visionary Science at Frost and Sullivan

The aerospace industry continues to remain at the forefront of composite adoption, primarily due to the market’s proactive shift toward lightweighting to meet emission reduction goals and increase fuel efficiency. However, in comparison to other industries that have embraced composite technology, the approval process for new materials in aerospace takes a significant amount of time and opportunity cost is high.

Nonetheless, over the years key aerospace OEMs understood the significant advantages of composites over metals in terms of design flexibility, vibrational damping and a high strength-to-weight ratio. Therefore, OEMs have since used composites for primary load-bearing structures and high-volume components such as wings, fuselages, elevators, rudders, ailerons and nacelles. And more recently, composites have penetrated secondary applications, including windows, cabin compartments, arm rests and trim strips due to their superior fire, smoke and toxicity (FST) properties, as well as antimicrobial properties.

Within the composites market, carbon fiber reinforced polymers have been the primary beneficiary of the industry’s answer to lightweighting. The share of carbon fiber composites is likely to further increase in the coming years, owing to the tremendous potential to replace aluminum and steel in primary load-bearing structures. In addition to this, carbon fiber composites remain the dominantly used material within the aerospace segment because of its adoption in fan blades, spinners, ducts, thrust reversers, vent tubes and engine cowlings. However, with the demanding nature of the aerospace industry, the carbon fiber upstream value chain continues to face challenges such as cost and supply.

Due to the reduced requirements on impact resistance for interior applications, along with lower material and production costs, glass fiber reinforced polymers find opportunities mainly within interior applications. At the outset, composite usage in interior applications has also been driven by increasing interest in enhancing aesthetics, especially in business and first-class segments, with passenger cabins also expected to become more advanced in the future.

Even though most of the discussions surrounding the use of composite technology get confined to fibers, resin matrices play an equally critical role in performance. Thermosets such as epoxies continue to be the most dominant resin matrix in carbon fiber composites and will find growth in structural applications because of the material’s superior mechanical properties and chemical resistance.

The industry’s adoption of thermoplastics has been cautious due to conservatism in material qualification and airworthiness certification. However, due to advances in processing technology and benefits such as recyclability and cost, high-performance thermoplastics such as polyetheretherketone (PEEK), polyaryletherketone (PAEK), polyetherimide (PEI) and polyphenylene sulfide (PPS) are competing with thermosets and are on the cusp of gaining ground in certain structural and interior applications.

The biggest threat to growth in composites comes from advances in competing material technology. Alloys of aluminum continue to be the mainstay when it comes to most of the aircraft models, while composites have found opportunities in larger aircraft platforms. Manufacturers of competing materials are also striving to develop next generation alloys that are expected to compete with composites on functionality. While aluminum alloys mainly compete with composites in structural applications, materials such as super alloys and titanium technologies are increasingly finding growth in aero-engine applications due to their superior tribological properties and thermal performance.

The commercial aerospace industry, which has largely been the driver for composites usage, is expected to grow at 5.5 percent through 2022. With a number of aerospace OEMs focusing on composite-intensive models, the demand in aerospace applications is likely to witness strong growth in the near term. The Boeing 787, Boeing 777X and Airbus A350 XWB will primarily lead this effort. In addition, the C-919 from the Commercial Aircraft Corporation of China, Ltd. (COMAC), which utilizes advanced composites for a big chunk of the body, will be an additional avenue for opportunities.

In the longer term, composites also will be expected to find adoption in business/general aviation programs, which in comparison to the commercial aircraft programs previously mentioned are relatively smaller.

U.S. Composite Materials Market Forecast by Application Segments

Source: Lucintel’s market report, “Growth Opportunities in the Global Glass Fiber Market”
The Carbon Fiber Market
By Daniel Pichler, Managing Director of CarbConsult GmbH

In 2016, global demand for carbon fiber increased at a healthy rate of 12 percent to 70,000 metric tons, consistent with the growth rate over the previous two years. Over the last six to seven years, the growth rate has averaged a respectable 10 percent. Not surprisingly, markets driving that growth include aerospace, wind energy and new emerging applications in automotive. Depending on which forecast is used, those markets account for between 35,000 and 45,000 metric tons, and are all of a similar scale.

Many see high potential growth for carbon fiber applications in infrastructure and construction applications given the sheer volume of aging infrastructure in need of repair or retrofit in the U.S., as well as around the world. While infrastructure and construction applications account for only 5 percent of today’s market, the upside potential is significant.

The demand for pressure vessels could grow for the compressed natural gas (CNG) market, both for storage and transportation vehicles, and eventually for hydrogen storage tanks to power fuel cells. As the technology and economics to produce CFRP pressure vessels improves, this technology will be more attractive even at low to moderate energy prices.

Automotive is the segment everyone looks to for significant growth over the next five to 10 years and beyond. Certainly, BMW has led the way with the i3/i8 program, as well as the Carbon Core in the 7-series. The trend toward electric vehicles will create increased demand as automakers leapfrog each other to increase range and make electric vehicles more attractive to a wider range of buyers.

In addition, the new high ground in transportation will be automated vehicles, including trucks, buses and automobiles. OEMs will rethink their approach to the market, and features such as durability in high-use applications and space-to-weight ratios will increase demand for efficient, lightweight CFRP parts and structures.

At just an 8 percent growth rate, carbon fiber industry volume would increase to 125,000 metric tons by 2025, which is the minimum being forecast. This is more than double the level of carbon fiber production from 62,000 metric tons in 2015. And there are a number of scenarios in the automotive market segment that can have a significant further impact on carbon fiber production: Individual programs can be large, so it’s possible that the industry could grow even faster and be three or four times larger by 2025. However, automotive carbon fiber opportunities in the “millions of pounds range” are probably better aimed at part replacements than programs designed to build whole CFRP cars from the ground up like the i3.

Estimates of capacity utilization in the carbon fiber industry vary widely, with some estimating between 40 and 100 percent excess capacity, depending on whether you use nameplate or effective capacity respectively. Despite this estimated imbalance, capacity continues to expand globally. Is this being done in anticipation of substantially increased demand? Why are so many suppliers investing in capacity? With so many new companies and new plants in many countries, these are the Wild West days in the industry. Just as the west was tamed, so too will the carbon fiber industry be shaped by a number of forces.

Scale will drive efficiency, especially in captive programs with automotive OEMs who need a secure source of supply. Precursor knowledge is the key to technological leadership, given the fact that precursor costs are half (or more) of the final cost of a pound or kilo of carbon fiber and the quality of precursor has a significant impact on final carbon fiber product quality. Captive programs also allow for greater customer intimacy, helping carbon fiber producers to improve quality and value for the end user.

In conclusion, the carbon fiber industry is developing in a dynamic way, at a rapid pace. The future? All we know for certain is that it will be bigger than today – much bigger.

The Automotive Market
By Marc Benevento, Managing Director of Industrial Market Insight

At nearly 4 billion pounds in 2015, composites represented about 1 percent of all materials used in light vehicle production, by mass, including applications to both the vehicle body and interior. Although the market share of composites is relatively low, rising regulatory requirements and consumer demands are creating a wave of opportunity for composites in automotive body structures, and suppliers are working diligently to seize it.

Industry forecasts predict annual growth rates of 6 to 9 percent for automotive composites over the next several years, due to the ability of carbon fiber composites to help manufacturers meet increasing fuel economy and safety regulations. However, these growth forecasts are predicated on the industry’s ability to successfully meet challenges related to cost, cycle time and end-of-life concerns, which will require breakthroughs in materials and process technologies.

The largest growth opportunities in the automotive industry exist in body applications, where composites hold only a fraction of a percent of market share today. Demand for lightweight...
High strength steel and aluminum have gained market share as manufacturers have looked for cost-effective methods to reduce vehicle weight. Despite its higher cost versus steel, aluminum gained nearly ten points of market share in mainstream vehicle body structures in the past decade, as manufacturers became more willing to pay a premium for weight savings.

Manufacturers seeking even more aggressive weight reduction have begun experimenting with carbon fiber composites, even though they typically cost several times more than steel or aluminum. The most prominent examples are from BMW. The automaker formed a partnership with carbon fiber supplier SGL prior to producing the i3 and i8 electric and hybrid vehicles, which both have CFRP intensive body structures. The i3, in particular, broke new ground for composites, as BMW has produced upward of 30,000 units per year, and it is sold at a price point well below the superscars normally associated with the material. The i3 platform alone is estimated to consume about 10 million pounds of CFRP annually, representing a major victory for the industry.

After using the i3 to develop manufacturing technology and a supply chain capable of handling high production volumes, BMW introduced the industry’s most advanced body structure with the 2016 7-series. The unique structure combines CFRP with metals, placing the expensive composite material exactly where it will benefit the vehicle most from a cost and performance standpoint.

Although CFRP accounts for only 3 percent of the 7-series body by weight, the material is credited with contributing 40 kilograms of weight savings, helping achieve fuel economy targets for the program. Due to the high cost of carbon fiber, it is likely that the practice of using the material sparingly – and in combination with more traditional automotive materials – is the way lightweight automobiles will be built in the future.

Thermoset CFRP has struggled to gain significant penetration in the market for automotive body structures for three primary reasons: part cost, cycle time and end-of-life concerns. Significant efforts are underway on each of these fronts, and much progress has been made. However, in order to achieve broad acceptance in the industry, several things must happen. First, it’s widely believed that the cost of carbon fiber will have to be reduced by at least a factor of two from its current level. In addition, cycle times of under one minute must be achieved. Finally, the material must by fully recyclable at the end of its life.

Therefore, a considerable amount of research is being done to develop low-cost carbon fibers compatible with thermoplastic resin systems, due to the processing speed and recycling advantages intrinsic to these materials. If low-cost thermoplastic CFRP systems can deliver mechanical and physical properties approaching what can be achieved with epoxy, they are likely to be successful. This is not a trivial task, but the result of these efforts will determine the future growth trajectory of carbon fiber composites in the automotive industry.

Due to changes in the regulatory environment, the current decade represents the greatest opportunity in 40 years for new materials to break into mass-produced automobiles. Composites will certainly benefit, and robust annual growth of composites is expected for the next several years. In the short-term, it is likely that thermoset resins will enjoy growth in body applications. To fully meet higher growth expectations over the long term, considerable technical hurdles must be overcome in both composite materials and processing, and thermoplastic composites are likely to play a large role.
value of our materials not only in terms of performance, but also in terms of environmental protection, which is a very hot topic inside the European Commission.

EuCIA has been actively working on waste topics (specifically, how composites are classified in the Waste Framework Directive) and on the impact of chemicals used for composites production within the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) regulation of the European Union, officially adopted to improve the protection of human health and the environment.

In line with these topics, EuCIA recently launched an EcoCalculator tool for performing an assessment on the environmental impact of composites using the lifecycle analysis approach (LCA). The tool is available free of charge until mid-2017 at http://ecocalculator.eucia.eu. The tool uses an inventory database specifically built using environmental data provided by material suppliers and converters in Europe. Proprietary data also can be used for the analysis. The tool provides a cradle-to-grave analysis output in the form of a PDF report and/or a file that can be used for further analysis using commercial LCA software.

As for new composite applications, EuCIA supports the activities of the European Committee for Standardization’s Technical Committee 250 (CEN/TC250) to develop European guidelines for the design of FRP structures as a support to the implementation, harmonization and further development of the Eurocodes for building and construction. Guidelines were published in 2016 by the European Commission’s Joint Research Center in Ispra, Italy, and are currently under public enquiry. The procedure of adoption into the Eurocodes is expected to be completed by 2020.

Unfair competition practices are currently striking the European industry, due to dumping (a pricing policy in international trade where products are sold below the cost of production) and subsidies from far-east major market players. In order to guarantee a level playing field for European producers, effective anti-dumping trade measures were introduced by the European Commission upon request of the European Glass Fibre Producers Association (APFE). Products currently subject to these measures are chopped strands, rovings and mats.

As for qualification of workers, at present there is no common program across Europe, and training is essentially managed independently by each country. This topic could be an opportunity to enhance cooperation with ACMA in the U.S., which has a very effective Certified Composites Technician (CCT) program. EuCIA plans to investigate if and how the program can be adapted to Europe.

The Airbus A350 XWB is one of several aircraft by major OEMs whose use of advanced composites will help drive demand for carbon fiber.

European GFRP Production

![European GFRP Production Chart]

*estimate

Source: Composites Germany
Meeting Next-Gen Consumer Demands

Suppliers, fabricators set the stage for greater use of composites in consumer electronics.

By Megan Headley
seven years ago, the consumer electronics market seemed ripe for opportunity for composites companies, says Ben Halford, CEO of Surface Generation, a United Kingdom-based provider of technology to help optimize the use of advanced composite materials. Numerous suppliers and fabricators were exploring ways to add their materials into innovative consumer solutions.

“What I see now is different, probably more realistic,” Halford says. Three years ago, he says, consumer electronics was all about trying to deploy virgin composites in mass-produced applications. Today, it is about providing strength to specific areas where support is needed.

Composites companies are looking for new ways to be part of those solutions – and drive the next wave of innovation.

Determining What the Consumer Wants

As dramatic innovation has slowed in devices such as smartphones and tablets over the last couple of years, consumer electronic designers have sought to rebalance priorities.

“Customers are asking for lower prices on the one hand, and at same time they expect an excellent stiffness, preferably at lower thicknesses and weight,” notes Jochen Bauder, managing director of Bond-Laminates GmbH, a subsidiary of specialty chemicals company LANXESS.

According to Covestro, consumers want their notebooks, tablets, TVs and smartphones to be ever faster, thinner and lighter – but also robust and sophisticated in design. And, of course, made from sustainable materials whenever possible.

Certainly, composite blends have contributed to thinner smartphones, laptops and tablets, even as they’ve helped increase stiffness. For example, HP’s newly-released Spectre lays claim to being the thinnest laptop ever, at only 10.4 mm. To attain that distinction, it blends aluminum with carbon fiber.

According to information from HP, the Spectre’s frame is CNC-machined aluminum. It’s the CFRP bottom that helps maintain a thin profile that is both durable and lightweight. That composite blend helps keep the notebook’s total weight at 2.45 pounds and, say product reviewers, make the thin machine feel sturdy in hand.

That blend – carbon fiber in support of traditional materials that dominate the consumer electronics market – is one area where composite suppliers may see growth.

“Carbon fiber is now being used where it genuinely adds value, both economically and technically,” Halford says. “We will put carbon fiber as reinforcement, but we’ll fill the details in with injection molding. That’s the trend. We’re using it where it should be.”

Prioritizing Power Over Size

Reviewers call the HP Spectre innovative in that it marries sleekness with power. Typically, going thinner for computers and similar electronics means sacrifice.

“It’s a tradeoff,” points out Halford. “You can either keep making it a thinner product or you can make it the same thickness and have a longer battery life.” In fact, some consumers have begun revolting against thinness.

“The latest smartphone is thinner than its previous reincarnation,” Halford says. “I don’t know about you, but there’s a point where I don’t care. We’re far reaching a performance plateau where improvements are incremental so the incentive to upgrade is minimal. Tablet sales are falling away because they’re a purely consumptive device. We don’t create on them, we just use them … . We don’t care about it being thinner or lighter, so what can carbon fiber realistically offer?”

And there may be other problems with going thinner. CNET explains the spontaneous fires that drove Samsung’s Galaxy Note 7 out of production like this: Phones powered by highly flammable lithium ion battery packs can have problems if a battery short-circuits due to, for example, a puncture in the overly thin sheet of plastic that separates the battery’s positive and negative sides. That tiny hole point becomes a path for electricity, which can heat the flammable liquid electrolyte quickly enough that the battery explodes.

But these are challenges that present opportunity for innovative technology companies. For example, KULR Technology Corp. is applying aerospace-based carbon fiber technology as a heat management solution for consumer electronics.

As electronic devices meet demand for more powerful performance, they generate greater levels of heat. A heat sink is used to disperse the heat and prevent overheating. Aluminum and copper-based heat spreaders and exchangers have been doing this job, but KULR seeks to replace these components with a highly flexible heat sink made from its proprietary carbon fiber-based technology. According to the company, carbon fiber thermal interface materials provide lower contact pressure, higher compliance and longer reliability than traditional materials.

KULR calls its material carbon velvet. According to an October 2016 Forbes magazine article detailing the technology, KULR can change the length and density of its fibers to change the heat transfer characteristics and cost. The velvet can reportedly ease the assembly of the final product by molding to body parts.

The article notes that the technology itself has been around for decades, but KULR’s proprietary manufacturing process could enable wider adoption of the carbon velvet technology at a more competitive price point.

Putting the Process First

As with KULR, many fabricators are focused on fine-tuning the behind-the-scenes production processes. It may not be as exciting as the end result, but production is an area where composites companies can redefine the scale of how their materials are used in the future.

After all, the consumer electronics market does scale in a way that few industries can rival. For example, a 2013 Wall Street Journal article reported that 500,000 iPhone 5Ss were being built per day. Compare that to the automotive industry; Toyota puts its daily production at around 13,000 cars. As a result, it’s critical that materials destined for consumer
electronics be suited to large-scale production.

It’s one reason that Bond-Laminates partnered with LEONHARD KURZ Stiftung & Co. KG to develop a new material combination and mold technology to produce thin housing parts in a single processing step.

The housing is made by injection molding Bond-Laminates’ semi-finished thermoplastic composite, ‘Tepe’x dynalite. The material combines high strength and stiffness, which allows for the thinness and light weight that consumers expect in their electronics. This strength also reduces the need to compromise on the mechanical performance of the decorated components, the company reports.

The product is decorated using an in-mold decoration process. The component is coated during the injection molding process, using a dry coating technology developed by KURZ that eliminates the need for a separate coating process step. By reducing steps, the new process also eliminates the need to store, transport, clean or pre-treat injection-molded parts prior to coating.

In addition, other features can be integrated into the injection molding process to further reduce steps and, consequently, costs. It’s technology that can be applied to any combination of consumer electronics.

“This could be any kind of housing in the field of consumer electronics – smartphones, tablets, notebooks, etc.” Bauder says. “But it could also be applied for shavers, hair-dryers, vacuum cleaners – wherever you want to achieve light weight in combination with stiffness and/or strength and a nice flexible decoration.”

**Applying Composite Benefits**

Faster production times that can reduce overall costs are one reason that thermoplastics like Tepe’x may be getting a closer look for future consumer products.

“It is in the nature of thermoplastics that the processing has shorter cycle times than thermoset-based composites,” Bauder says. However, he adds that the company demonstrated through its injection molding machines “that it is possible to reduce production process steps of thermoset-based composite parts from more than seven process steps down to one process step with this hybrid molding plus in-mold decoration process and by using only one tool.”

The sustainable aspect of thermoplastic materials is another appealing factor for consumers. Halford adds that, through down-cycling and thermoplastic matrices, carbon fiber suppliers are also finding ways to meet the demand for more sustainable products. “I have been sent recycled carbon fiber, reconstituted – a byproduct of aerospace – to be incorporated into products. That is a viable economic trend,” he says.

Covestro is blending the benefits of both materials with its latest offering. Its continuous fiber-reinforced thermoplastic composite solutions are based on films of endless unidirectional carbon fibers. These films are layered one on top of the other, cut, then laminated to produce stiff and lightweight composite sheets that don’t distort or shrink. The number, direction and sequence of layers can be altered to change the benefit, depending on the application.

The material choice addresses one of the chief complaints from product reviewers: the look of composite-based housings. Covestro says that the external appearance of its sheets differs from typical semi-finished plastics with their “organic” grain pattern. In addition, the materials are cool to the touch, due to their thermal conductivity, and sound like metals on impact, adding to consumers’ perception of product durability.

“They provide the best strength-to-weight ratio of all standard composites on the market and also outperform metals in this respect, which means they’re ideal for making parts for IT devices that are impressively robust despite their thin-walled, lightweight design,” commented David Hartmann, one of the heads of Covestro’s thermoplastic composites work, in a statement on the technology.

But driving the use of new materials in consumer devices has its challenges. According to Halford, the original equipment manufacturer brands will not single source. “So it doesn’t matter if I have the best nanotechnology on the planet. If I’m the only one, procurement will not be allowed to buy from me,” he explains. “The irony is you need an ecosystem realistically in China that’s already up and running to cope with the production ramp ups.”

Aside from the high cost, this marks a significant reason that carbon fiber will likely remain limited to high-end devices — and not your everyday smartphone as Samsung reportedly considered back in 2013 when it formed its joint venture with SGL Group, Samsung SGL Carbon Composites Materials. Using carbon fiber would require adaption of production processes.

Halford adds, “One of the things that China does incredibly well is scale, but what it doesn’t do is get carbon fiber properly, yet. We’ve been in factories where they just don’t understand it. They’re used to injection molding. They have maybe 1,500 injection molding machines in a ‘small’ plant, and six people who actually understand the process. If a supplier comes along with a new material, it better work on the existing machinery and cycles because they are not going to change those machines. So, when you turn up with carbon fiber, with +/-5 percent thickness variations, you’ve got some serious work to do.”

**Next-generation Innovation**

One reason that production processes are being redefined is that the next level of innovation in consumer electronics is coming. Getting “the next big thing” is what drives electronics sales, after all.

One possibility could prove intriguing for composite material suppliers. For several years trend watchers have been promising that Samsung and, later, Apple would deliver on patents for foldable smartphones at any minute.

The patents for these technologies give little insight into the actual mechanics, offering composites as but one potential material that may be used to produce this unique housing.

In June 2016, *Digitimes* reported that consumer electronics manufacturers in Taiwan are exploring production of foldable active matrix organic light-emitting diode (OLED) panels — the display on most high-end phones. The goal was to have work underway on bendable panels for smart wearable devices, foldable panels for smartphones and tablets, and rollable panels for monitors, notebooks and TVs by fall 2017.

Such panels may need to replace glass substrates with polyimide substrates and glass covers with composite covers, according to the report.

And what could be more flexible than a composite-based housing?

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A new year gives every organization a fresh chance to take stock of where they are and where they’re going. With change comes new opportunities, and it is ACMA’s job to capture those opportunities to benefit the composites industry and our members. Let’s explore a few of ACMA’s highest priorities for 2017.

Composites are the material choice for a litany of infrastructure applications. ACMA has had an aggressive and focused effort to grow the use of composites in infrastructure, and this will remain our top advocacy priority for the coming year.

One key objective is to ensure an effective rollout of the Transportation Research Board’s forthcoming study on the performance of composites used in the former Innovative Bridge Research and Construction program (IBRC). Under the IBRC, some 150 bridges around the country were built using various composite components. ACMA heavily advocated for the inclusion of the study provision in the FAST Act, signed by President Obama in late 2015.

ACMA also successfully advocated for inclusion of a requirement in the Water Resources Development Act (WRDA), approved by Congress in December, to study the performance of composites and other innovative materials in US Army Corps of Engineers civil works projects. Composites have been used by the Corps over the years but with limited regularity. Under WRDA, the Transportation Research Board will review the performance of composites and other materials and make recommendations regarding their inclusion in the Unified Facilities Guide Specification (UFGS). Inclusion in the UFGS is a necessary precondition to opening the door for the wider and more regular use of composites in Corps projects like dams, locks, levies and more. ACMA is committed to working closely with the TRB to ensure the study captures the positive performance attributes of composites.

The new year, new administration and new Congress present grand opportunities for leaders to address America’s crumbling infrastructure woes in a fundamental way. The Trump team has made rebuilding our infrastructure a priority. In anticipation of a significant infrastructure package in 2017, ACMA is committed to educating Congress and the administration on the superior...
value composites bring to infrastructure and to advocating for their further use. All infrastructure markets, from roads to water to the electric grid, are ripe opportunities to advance our industry.

Another priority for ACMA is to promote the use of composites in military applications. While widely used in aerospace and ballistic protection applications, composites are underused throughout the military. ACMA seeks to collaborate with the Department of Defense and various branches of the military to identify ways composites can be put to use. The National Defense Authorization Act will be a key instrument in advancing composites in defense, and we will work closely with congressional leaders from beginning to end of this year’s process.

Several federally-sponsored research programs are central to the growth and success of the American composites industry. IACMI-The Composites Institute is leading the way on cutting edge research on the next generation of composites materials for wind energy, lightweight automobiles and compressed gas storage vessels. ACMA will press Congress and the administration to ensure IACMI remains well-funded, well-managed and responsive to the real world needs of composites manufacturers, industry suppliers and customers large and small. The National Institute for Standards and Technology has committed to working with ACMA and our members to address industry standards and testing needs. This will help address voids that inhibit our ability to compete against other materials.

ACMA is equally committed to fighting for fair regulation of our industry. Last year, ACMA members educated OSHA about process safety issues faced by composites manufacturers and opened a discussion on styrene toxicity in preparation for the agency starting to update the workplace exposure limit for this substance. In 2017, we’ll likely see the opening rounds of industry communications with rule makers on EPA’s update to its air emission control standard and on OSHA’s new combustible dust standard.

This will also be an important time for composites manufacturers across the U.S. to come into compliance with California’s Prop 65 right-to-know regulations and for the industry to promote sound science for styrene risk evaluation at EPA’s newly-reformed Toxic Substances Control Act (TSCA) chemicals-in-commerce program and at Cal-OSHA for that agency’s Permissible Exposure Limits (PEL) update. Fire code bodies will also consider ACMA-recommended revisions to the codes for resin spray operations and storage of organic peroxides. We will also monitor local and state air regulatory agencies as they modify or adopt volatile organic compound (VOC) control rules to comply with EPA’s updated ozone standard.

They key element that ties all of our efforts together – and what allows ACMA to be a successful advocate – is you. By being a member, joining ACMA committees, participating in advocacy events and supporting PAC and grassroots programs, you can drive positive change on all of these issues. By unifying together, we can build a more vibrant future for composites and America.

MJ Carrabba is ACMA’s Associate Director of Government Affairs. Email comments to mcarrabba@acmanet.org. John Schweitzer is Senior Advisor to ACMA’s President. Email comments to jschweitzer@acmanet.org.

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North American Composites (NAC) has stocking locations across the United States and Canada providing local, personalized service to composites manufacturers. We deliver high-quality composite materials, accessories and equipment from the top suppliers. For nearly 40 years, our knowledgeable sales representatives have served manufacturers in aerospace, ballistic, construction, corrosion, energy, marine, transportation and other industrial and consumer applications.

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ACMA Special Election Report

The American electorate has chosen Donald Trump to be the 45th President of the United States. The Republican Party won the White House and also maintained control of both the House and the Senate. America voted for change, with the main theme of the election being rejection of the current establishment in Washington. What does a new Trump administration and Republican control of both houses of Congress mean for the composites industry? For insights on the impact of the election on composites and America, go to ACMA’s members-only Special Election Report at http://www.acmanet.org/regulatory-compliance.

ACMA Seeks Your Input to Best Serve the Industry

Providing a comprehensive set of high-quality resources and services to our members is a top priority at ACMA. If you work for an ACMA member company or organization, you will be invited via email to participate in ACMA’s Membership Satisfaction Survey. This is your opportunity to provide feedback on what’s working and not working within

New Members

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Rice, Texas

General Plastics Manufacturing Company
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our organization and to help us identify areas where we can better support our members. For more information, contact Paul Hirsh at phirsh@acmanet.org.
CCT Seeking Experts

ACMA’s CCT program is seeking members with technical expertise in basic composites and wind blade repair technology who are willing to assist in updates to Certified Composites Technician course material. Individuals currently working in manufacturing, materials, training, field operations, technology development and applications are well suited for this role. Current CCT instructors, engineers, manufacturing supervisors and technical experts are also candidates with valuable input. The project consists of individual review and input on draft material followed by several phone/online meetings with the subject matter expert team to review and refine material. Please contact Andrew Pokelwaldt at apokelwaldt@acmanet.org if you are interested in becoming part of this team.

Upcoming Infrastructure Workshop and Fly-In

On February 8-9, ACMA and the National Institute of Standards and Technology (NIST) will host an infrastructure workshop at NIST headquarters in Gaithersburg, Md. The workshop will provide an opportunity to discuss obstacles to commercialization of composites in infrastructure. It is intended to identify improved data, standards and specifications, and predictive tools that would enable a more rapid commercialization of composites for a sustainable infrastructure. This workshop is being held in conjunction with
Be a Guest Writer for Composites Manufacturing!

The ACMA Communications team is seeking members with technical expertise and writing skills who are willing to submit materials and articles for Composites Manufacturing. Individuals currently working in composites recycling, upcoming innovations and renewable energy should contact Barbara Sadowy at bsadowy@acmanet.org. While these articles are editorial in nature, this is a good way to demonstrate expertise in a subject area and receive visibility for your company.
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