The “Wow” Factor: Eye-catching Applications

A Look at Surface Finishes

Opportunities in the Pipe & Tank Market

November/December 2016

Composites Manufacturing

The Official Magazine of the American Composites Manufacturers Association

www.compositesmanufacturingmagazine.com
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About the Cover:
The Elytra Filament Pavilion at a London museum is made from robotically-wound carbon fiber and fiberglass components.
Photo Credit: © Victoria and Albert Museum, London
The year is coming to a close, and as I reflect back on all my activities, the highlight of my year was CAMX – The Composites and Advanced Materials Expo. I hope you had an opportunity to travel to Anaheim and see all the excitement and energy in our industry.

We had nearly 8,000 attendees at the show from more than 50 countries, including 1,600 first-time attendees. They represented different areas of the composites industry, but all came with one goal: to learn, grow and be inspired. ACMA focused on bringing students to the event, with multiple universities represented and over 40 poster presentations on groundbreaking composites research. I was particularly inspired by the student panel discussion at the CAMX closing luncheon. Hearing the students’ bright ideas left me feeling very good about the future of our industry: They are passionate about the unlimited possibilities for composites.

The exhibit hall was full of activity and energy, too. What struck me the most was the investment companies are making in the industry and the way they showcased it in their booths and presentations. Walking the aisles, I saw complex booths with meeting space where industry professionals could collaborate. Also on display were finished products (including cars and bicycles) as well as raw materials (such as fabrics, resins and additives) and processing equipment in action.

CAMX Live! was the highlight of the week for me. Three speakers from diverse backgrounds shared how composites can inspire and impact the world – through innovative design, expanded connection to information throughout the world via the internet and eco-friendly manufactured and designed vehicles. (One of those speakers, architect Greg Lynn, shared more ideas with Composites Manufacturing in this edition of the magazine on page 10.)

I hope you had the same fabulous experience I did at CAMX. It is the perfect example of how ACMA is working on your behalf to grow the composites industry. If you didn’t get an opportunity to join us in Anaheim, be sure to mark your calendar for next year’s CAMX in Orlando, Fla., Sept. 11 - 14, 2017.

As always, thanks for your support of ACMA. Your dedication is what makes our industry great. I wish you and your family a happy holiday season.
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Selecting Sandwich Core Materials

By Russell Elkin

When it comes to composites, you have probably heard this before: "There are so many factors that influence the selection of [fill in the blank]." Some argue that selecting a sandwich core material is even more complex due to the extremely wide variety of products available.

Today, there are various tables, matrices and apps available to users that rank different products, all designed to simplify the selection process. The difficulty for core materials, however, is that when these tools assess a product, they only look at the base material. Choosing a sandwich core is not as simple as selecting end-grain balsa or Nomex® honeycomb. Each product has three parts: type, density and configuration.

Furthermore, the categories in these evaluation tools often do not align with what is important for each specific application, and the rankings are more often based on assumptions than test data. In addition, one category is almost always missing – cost. A proper evaluation should take all of these elements into consideration with the understanding that density, configuration and thickness can all be tailored to meet the part’s demands.

When selecting sandwich core materials, the first thing to do is create a list of critical parameters for your specific application, part geometry and manufacturing process. Ask these two questions:

1. What will be built?
2. How will it be laminated?

Application consideration has two parts: structural design and environment. Core material properties critical to structural design include shear strength and modulus, compression strength and modulus, and skin-to-core bond strength (tensile/peel). Furthermore, the application may have a particular requirement, such as fatigue or damage tolerance (impact). Damage tolerance is often ranked by measuring a material’s shear elongation. However, elongation is not the only important property with respect to energy absorption under impact; shear and peel strength are also critical.

In addition, it’s not as clear-cut as just ranking different materials based on strength, modulus and so on because these properties are dependent on density. Many products, particularly cellular foams, can be manufactured in a very wide range of densities, some of which have greater benefits than others. For example, while low density urethane foams can be weak, higher density urethane-based core materials can be extremely strong.

Other behaviors may depend on the configuration or finishing option. For instance, the damage tolerance of styrene acrylonitrile (SAN) foam is excellent if laminated in rigid sheets, but the behavior is vastly different if a flexible (scored) configuration is used.

Sometimes the selection process will be straightforward. For instance, the list of core materials with compression strength greater than 700 psi is pretty small. For most other parts, you should first eliminate materials that have insufficient mechanical properties, then evaluate the remaining products that provide the best performance at the lowest density and/or price.

In addition to creating your own matrix, there are many simple laminate evaluation tools available that allow the user to compare different materials. Be aware, however, that some do not take the properties of the core into consideration. These will not be very useful if you want to compare sandwich core materials.

Aside from mechanical requirements, you should consider the part’s operating environment. Will the part be exposed to water, chemicals or high or low temperatures? Does it need to be fire resistant? Again, product density plays a role. Generally, higher density foams have better corrosion and temperature resistance than lower density materials of the same polymer. The sheet configuration can also affect performance as well as the lamination process.

Throughout the selection process, keep in mind that some aspects of a part’s behavior are not exclusively attributed to the core material. For example, changing the resin may vastly improve fire resistance.

Another critical consideration is the lamination process. Important features to reflect upon are resin compatibility (styrene resistance), temperature resistance (dimensional stability) and open cell content. For certain foams, resistance to styrene is generally dependent on density. (Lower density is less resistant.) Also keep in mind that foams not designed to operate at high temperature are fully capable of withstanding the heat from resin exotherm, so don’t mistakenly eliminate materials because you fear that the resin will get hot: there is a difference between short-term temperature spikes from exotherm or post curing and long-term exposure with an elevated temperature cure.
Once the material is selected, the manufacturing process and geometry of your part will determine the core’s configuration or finish. Here’s where proper core installation comes into play. Often bad performance is blamed on the core material, when poor quality laminate was the cause. Always follow these rules:

1. Avoid “never bonds.”
2. Fill the kerfs.
3. Fillet all core edges.
4. Segregate the core from all openings.

This brings us to total cost, which is a combination of the core material, finishing and resin absorption. Let’s take a look at all three:

**Material:** Look for value. Often the lowest cost product will not produce the least expensive part. It is quite easy to determine which products produce the best “bang for your buck.”

**Finishing:** Unless you are building flat panels in a press, all core materials (besides honeycomb) should be perforated or otherwise scored to allow air and other gasses to escape from under the core. Sheets must also be cut to conform to curved surfaces. Certain foams may be thermoformed to produce lighter parts. Grooves may be added to promote resin flow.

**Resin absorption:** Balance conformability with resin uptake. Treatments are also available to reduce the amount of resin absorbed by the core when infused.

Overall, the proper selection of a sandwich core material may seem like an arduous task, but many questions answer themselves fairly quickly. If you apply the “right tool for the right job” maxim, then sandwich core materials will help you build better parts with greater quality and improve your bottom line.

The guest columnist for this issue’s “Best Practices” column is Russell Elkin, Product Development Manager, USA for Baltek Inc. Email comments to russ.elkin@3acomposites.com.

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More “Best Practices”

If you’re looking for more practical guidance on composite materials and processes, check out all the Best Practices columns from the past two years. Industry experts cover everything from composite repair to resin selection. Visit CompositesManufacturingMagazine.com and read the Best Practices articles under the “Columns” tab.
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In 1999, pilot Bertrand Piccard had a radical idea – build a plane capable of flying night and day without using any fuel, propelled solely by solar energy. Four years later, after Piccard conducted a feasibility study with mechanical engineer and pilot André Borschberg, he and Borschberg began the Solar Impulse project.

The first plane in the project, Solar Impulse 1, completed successful solar-powered flights across Europe in 2012 and a multi-stage flight across the U.S. in 2013. Looking to improve the prototype, the company developed its successor, the single-seater Solar Impulse 2 (Si2), made of 17,248 solar cells that supply the plane with renewable energy. The goal for the Si2: complete a trip around the world.

While the idea behind the Si2 seemed exciting, many major players in the aerospace industry were skeptical, according to Bernd Rothe, the former Solar Impulse project manager who now serves as Covestro’s plant manager: “[When Solar] Impulse asked Airbus, Boeing and all the big airplane manufacturers if they wanted to also cooperate in the project, they all said, ‘That’s an idea which will not work, and we are not interested.’”

However, after years of designing and testing the aircraft, those OEMs were proven wrong on July 26, 2016, when the Si2 returned to Abu Dhabi on the final leg of its 16.5-month, round-the-world journey. According to Solar Impulse, composite parts from Solvay, Covestro and North Thin Ply Technology (NTPT) played a major role in the success of the Si2. Approximately 83 percent of the aircraft’s structure is made with composites. The structure incorporates carbon fiber sheets that are three times lighter than paper.

Rothe says that making the aircraft that light was possible because its composite material suppliers did not have the usual constraints of an Airbus- or Boeing-level aerospace project. “Let’s be honest, price and also production time are not really major factors because [Solar Impulse] just needs to produce one airplane,” Rothe says. “If the price is little bit higher than normal, that’s also OK, because the goal is to make it as light as possible.”

Claude Michel, the head of Solvay’s partnership with Solar Impulse, described that goal as “an obsession.” Overall, the plane is roughly the same size as a Boeing 747 and weighs just 2,300 kilograms (5,070 pounds) – which according to Solar Impulse is the largest aircraft ever built with such a low weight.

The aircraft’s wing spar was divided into three parts: middle, left and right.
According to Michel, Solvay made the middle part entirely of carbon fiber Nomex® honeycomb sandwich panels impregnated with Solvay’s Torlon® PAI (polyamide-imide) thermoset resin. North Thin Ply Technology worked on the other two parts of the wing spar. NTPT spread M46J 12K ultra high-modulus PAN carbon tow from Toray to make unidirectional tapes. The tapes were resin-impregnated during the process and then converted into ±45° preforms up to 27 x 1.2 meters using NTPT’s automated tape laying machine.

Solvay and NTPT’s preforms for the wing spar were manufactured by specialist Decision SA using an out-of-autoclave technique, which allowed the company to create large composite molds and parts at low cure temperatures.

“Obviously, autoclaves that you would normally use are really expensive,” says Claire Michel, global marketing communications manager at Solvay. “Being able to manufacture it out-of-autoclave means cheaper infrastructure and the ability to manufacture something a lot bigger.”

In addition to the two wing spars, NTPT’s thin ply epoxy prepregs were used for the aircraft’s fuselage and empennage. Solar Impulse says the thin plies for the fuselage reduced the weight of the carbon fiber sheets from 100 g/m² to 25 g/m².

Covestro contributed to the aircraft’s cockpit cladding, door hinges, engine cowling, wings and cockpit windows. The company used a polyurethane resin system with a biaxial carbon fiber fabric as the matrix. Rothe says the door hinge was made by high-pressure resin transfer molding (HP-RTM) and that Solar Impulse built and adapted a special mold during the optimization process. Covestro partnered with a mold manufacturer experienced with RTM molds and a design team to help with an optimum 3-D design. Rothe says the feedback and exchange with Solar Impulse composite experts helped to make the composite parts as lightweight as possible.

However, according to Claire Michel, there was more to the Solar Impulse’s composite construction than simply achieving light weight. “[With composites], you can manufacture very complex [parts] in one step,” she says. “You can integrate components and cut down the number of parts. That in turn cuts down on the cost because you need less labor, less equipment in your factory, less tooling. You will also have reduced your emissions.”

According to Solar Impulse, the company’s next major project will be joining Google, Airbus and Facebook in the solar-powered drone race. Solar Impulse’s proposed drone, known as High Altitude Pseudo-Satellite (HAPS), may also be constructed with composites.
World-renowned architect Greg Lynn captured the audience’s attention at the CAMX General Session earlier this year with stories about the intersection of architecture and composites. “It might be because I’m a sailor, but I have a bias against metals and mechanical connections. I love to glue stuff, and your industry is a world that lives on glue,” he quipped.

After the presentation, Composites Manufacturing magazine’s Managing Editor Susan Keen Flynn sat down with Lynn for an exclusive interview. The owner of Greg Lynn FORM talked about his work as an architect as well as a professor in UCLA’s Architecture and Urban Design program and Chief Creative Officer of Piaggio Fast Forward, a pioneer in the lightweight transportation sector.

Q: Do you recall when you first heard about composites?
A: Fiberglass composites are something I’ve been aware of from the time I was a Cub Scout. I grew up a sailor with some familiarity of mostly how to repair, but also use composites. The cost, the cycle time, the availability – that’s the stuff I didn’t know about until later.

Q: During your CAMX presentation, you discussed your first professional project using composite materials. Tell us a little more about it.
A: The first contact I had with composites is a chair that I did for [furniture company] Vitra called the ravioli chair. Most chairs have legs, a seat, a back – oftentimes you’ll get arms. Chairs are built out of maybe two dozen components minimum, sometimes with hundreds of components and fasteners. We tried to build a chair with just two parts. It has a hard composite base and a composite platform on the top with injection foam bonded to it, then a 3-D knitted top, much like a contemporary athletic shoe.

Q: Any surprises during that project?
A: I hadn’t really understood just how light the material was. When we tested the prototype, the chair would slide when people sat in it. It was too light. So then the question was how do we add weight? That was interesting! The company adds weight at the showroom because we don’t want to ship metal ballast around.

Q: What attracts you to composites?
A: It’s the forms that are possible and the ability to integrate parts – to not have fussy details and connections. Architects make a whole lot out of the detailing. It’s all about bolts and screws and mechanical assembly. And I love the idea of getting rid of that stuff.
Q: In what circumstances are composites well-suited to architecture?
A: It takes some tenacity to convince the person who is inspecting your design to let you put composites where they really should be. Right now, it's very easy to use them for cladding, rain screens and interior finishes below a certain thickness. Historic preservation is almost all composites... That's the low-hanging fruit. Where it really gets interesting is in a high-rise building, constructing the upper floors with a 20 to 30 percent weight savings in secondary structure and the primary building envelope. The earthquake loads reduce exponentially with a reduction of mass up high due to inertia.

Q: What is some of the high-reaching fruit you are pursuing?
A: Vertical circulation in buildings is something we are thinking about with Piaggio Fast Forward and will be launching in early 2017. The same way you have ducts, plumbing and wiring for building services, we're looking at ways to have lightweight composite vehicular circulation in buildings for moving goods around. Think about the bank where you have a pneumatic tube move transactions and just scale that up to something the size of a table or chair so you're able to move things around within a building. Eventually, we'll look at moving people around in buildings that way, too.

Q: Another innovative project you talked about in your CAMX presentation was the microclimate chair. Can you talk a bit more about that?
A: I'm working with Nike on a microclimate chair for athletes that is inspired by, but not limited to, basketball players during the game. We've integrated sensing control systems into a single composite shell and take advantage of the conductivity of carbon to produce a temperature and humidity-controlled microclimate. The chair senses temperature, moisture, weight, pressure and movement, then feeds that information into a small processor. You get a baseline and then measure how an athlete's body is changing during the game and modify the temperature and air flow of the chair surface accordingly to bring down the core body temperature, while heating up a certain muscle group so the athlete doesn't cramp up.

What I think is most interesting about this is the material. I believe it's the first continuously changing, hard-to-soft material that's been done with a composite. It was created with two resin systems and North TPT [Thin Ply Technology] prepreg tape technology, with laminated Peltier [thermoelectric cooling] chips built in.

The microclimate chair is very cool because it's so immersive... If you look at what an elite player goes through after a game – which is sometimes up to two hours of treatment to keep them from being injured – getting some of that knowledge during the state of play is a huge performance advantage.

Q: You are clearly very forward-thinking, so where do you see the marriage of composites and architecture headed?
A: It will be a multi-pronged front. For me, it's getting architects to push the use of the materials. The contractors and building owners aren't going to push it... In southern California, all the major architecture schools do immersive, weeklong workshops on composites. I think that's probably where to start – with the universities.

Q: What can composites industry professionals do to help further infiltrate the architecture market?
A: Getting into the building industry is harder [than other markets] because it's a very diffuse industry. It's not like you can just knock on the door of big companies like GM, Ford and Apple. I believe it requires getting into the universities, taking on the right pilot projects and then going to some of the bigger architectural and engineering practices. It's an exciting industry, but it will take some work to penetrate.

Susan Keen Flynn is managing editor of Composites Manufacturing magazine. Email comments to sflynn@keenconcepts.net.

For more information on composites in architecture, visit ACMA's Education Hub (www.acmaeducationhub.org) to purchase or download Guidelines and Recommended Practices for Fiber-Reinforced-Polymer (FRP) Architectural Products.
A consortium in the United Kingdom has developed a prototype of the world’s first composite cruise ship cabin, which reduces cabin weight by 50 percent.

“It has caused quite a storm,” says Nigel Spooner of Nigel A. Spooner & Associates, a consultant on the project for Trimline, a marine outfitter in Southampton, England. “Since we completed the project at the end of March, we’ve had six major ship owners come to us because we’re saving about a ton per cabin,” he says. “For a new build with 2,000 cabins, that’s a savings of 2,000 tons!”

Tom Royle of Wizz Consultancy Ltd., project manager for the consortium, says that the project began in 2009, when Carnival Corporation invited representatives from the composites industry to tour the Queen Victoria, a luxury cruise ship operated by its Cunard cruise line. “We walked around pointing out various things that could be made from composites,” he recalls.

By 2012, discussions with Carnival began to focus on composite cabins because they are non-structural, making them a better fit with current International Maritime Organization (IMO) regulations. After a promising feasibility study conducted by Gurit, Royle assembled a consortium that applied for and received a government grant in 2013 from the Department of Trade and Industry’s Technology Strategy Board (now known as “Innovate UK”) to develop a lightweight composite cabin. Consortium members included PE Composites as lead partner, Carnival, Gurit, Trimline, University of Southampton and Lloyd’s Register, a certification body with regulation expertise. The Maritime and Coast Guard Agency (MCA) had an advisory role regarding regulations.

The project’s first challenge was determining cabin specifications. Royle says it was a surprise that Carnival couldn’t provide them. “Carnival doesn’t buy cabins, it buys ships,” he explains. “We couldn’t go to the ship builder for specs because we were building a competing product, and Carnival couldn’t release them because of confidentiality.” So the team reverse engineered a standard steel cabin by conducting finite element analysis and “pushing and pulling” existing cabins to test how they moved against different types of loads.

The next challenge was finding materials that would meet IMO fire regulations. Present day cabins use steel sheets that are 0.65 to 0.8 millimeters thick with 20 to 25 millimeter mineral wool bonded to the rear face. Some have a second sheet of steel applied to the other face of the mineral wool to form a sandwich.

The team considered mimicking this approach with thin GFRP sheets backed with mineral wool, but decided the sheets would be too heavy. Eventually, they opted for a code-compliant core sandwiched between single layers of low-cost, woven glass fibers that are impregnated with a resin that meets IMO fire test requirements for calorific value and flame, smoke and toxicity (FST) properties.

The panels for the prototype cabin...
were fabricated at PE Composites on the Isle of Wight using large flat tables, vacuum bag processing and conventional oven curing. The walls feature eight panels – two sides, two end walls and four smaller panels that form the cabin’s wardrobe and encompass the “wet unit” (toilet, sink and shower module). The GFRP deck head (ceiling) includes a rectangular recess or ‘coffer’ to hide air conditioning ducts and provide an improved lighting scheme.

Royle says the team spent more time talking about how to affix the panels to each other than anything else. They considered composite extrusions and angles, but decided to use steel angles because the cabins are expected to be assembled in shipyards. “You don’t have laminators in shipyards; you have metal workers,” says Royle. “We recognize that we are trying to move new technology into a metal industry. So the focus was always on what is the easiest possible way to assemble this.” The new cabin also has a steel bottom channel so that it can be welded to the deck like a conventional steel cabin.

After the panels were completed, Trimline assembled them into a 20-foot, 4.1-inch-long, 8-foot 10.2-inch-wide and 7-foot, 2.6-inch-tall cabin – the same dimensions as a typical Carnival balcony cabin. Trimline also outfitted the cabin, including lightweight composite furniture made from the same materials as the cabin. Aside from being significantly lighter, this furniture performs much better in a fire than furniture manufactured from standard materials approved by the International Convention for the Safety of Life at Sea (SOLAS), according to Royle.

Royle and Spooner both emphasize that the composite cabins not only save weight, but also bring significant changes to interior design. Steel cabins have vertical wall seams every two feet, ceiling seams every foot and a thin vinyl film coating that has a wood grain or other common pattern. The result, Royle says, is unattractive and “the same the world over.” In contrast, he says, the composite walls are seamless and can be painted, providing the freedom to create “a cabin that looks like no other.”

Composite walls are also easier to maintain. Steel cabins are easily dented and difficult to repair because the vinyl coating must be stripped and reapplied each time, says Spooner. Conversely, composite walls are difficult to dent. And if they are, the walls can be easily dry-filled and painted in a few hours.

Royle says that the prototype panels took several days to complete and included too much hand finishing. The next stage of the project is to move from the technology demonstrator to a commercially viable product capable of being manufactured in the quantities required to satisfy the new build market.

In the meantime, the cabin has created a great deal of interest among ship owners and cruising aficionados. Spooner says of early visitors, “We wanted to make people’s jaws drop when they walked in, and we’ve done that.”

Melissa O’Leary is a freelance writer based in Cleveland. Email comments to msh144@case.edu.

For more stories like this, visit CompositesManufacturingMagazine.com and check out the Marine articles under the “Market Segments” tab.
lots of composite applications are the workhorses of the industry, remaining largely unheralded: corrosion-resistant pipes that are buried underground, lightweight components under the hood of an automobile, FRP rebar hidden inside concrete. But sometimes composites take center stage, turning the heads of those who pass by and eliciting a whispered, “Wow!”

Here are five such applications, from an over-the-top yacht to a wind blade the size of a football field.

In 2012, boat builder Silver Arrows Marine partnered with Mercedes-Benz Style, the automaker’s design brand, to create a luxury yacht nicknamed the “Silver Arrow of the Seas.” The first pre-production yacht – aptly named “Mercedes” – was unveiled in April 2016 on the French Riviera.

The two companies spent two years on research and development, then testing. The pre-production yacht was built in 2014 and 2015. Upon its launch, Silver Arrows Marine Chairman Rob Gibbs said in a press release that the 10-passenger Arrow460-Granturismo “combines the best marine engineering with the inspired innovations and elegance that the world associates with Mercedes-Benz.” Some of its features include an open-plan cabin area, side windows that withdraw into the body, a retractable sunbathing platform in the stern, an interior coated in eucalyptus wood, two 480-horsepower diesel engines and an electronic system operated via touch panels and tablet computers.

The yacht’s structure is made completely of composites, including the hull, sides, deck and bulkheads. Several other components on board are also constructed of composites, including equipment supports, casings, the entrance door, hatch covers and exterior seats. A spokesperson at Silver Arrows Marine
says strength, light weight and an exceptional finish were the company’s construction priorities, so the boat builder relied on a selection of materials from supplier Gurit AG.

The main material used was Gurit’s single-sided SPRINT® ST 94, consisting of a layer of dry reinforcement (both carbon fiber and glass fiber) plied to a precast, precatalyzed epoxy resin film. “It is known not only for its extremely good balance of mechanical properties, but also its impact performance and resistance to resin microcracking,” says the spokesperson for Silver Arrows Marine. He adds that the material is specially developed for use in large marine structures where materials need to remain intact in the mold during long build times. In addition, the yacht incorporates SparPreg™ unidirectional epoxy prepreg and Gurit® Corecell™ M foams in various densities, including M80, M100 and M200.

Composites construction (including lay-up, vacuum bag molding and vacuum infusion) and assembly on the prototype took 14,000 hours. Prior to lamination, the core materials were thermoformed to create the complex curvature required for the deck and hull. Sandwich materials were cut to shape, heated to 105 C and then vacuumed to the mold. Next, layers of SPRINT prepreg, combined with sandwich materials, were added in various densities and thicknesses, depending on the area of application. After each layer, the boat builder performed a splash vacuum for a few seconds to stabilize the plies to the complex structural shapes.

The weight of the completed composite structure is approximately 7,200 pounds, accounting for less than 25 percent of the total weight of the yacht. According to Silver Arrows Marine, that figure is around 35 percent for most yachts.

The exterior of the Arrow460-Granturismo requires 78 individual molds. The hull is made in four parts, while most boats in this class size use just one, according to Silver Arrows Marine. “This is partly because so many shapes are curved and complex, but also to ensure all the parts can be replicated for production in the future,” says the company spokesperson. “There has been an emphasis on producing high-quality, production-friendly parts so future boats will be assembled in the most time-efficient manner.”

Silver Arrows Marine has begun marketing the Arrow460-Granturismo, rumored to have a starting price tag of $1.7 million. The boat builder anticipates production to start by the end of the year.
Over the past few years, the world has adopted new ways of getting around. While traditional taxis aren’t completely obsolete yet, many people now use Uber – an app that lets you summon a driver from wherever you are to get you where you want to be. However, one company, Chandler, Ariz.-based Local Motors, has introduced technology that could take the driver out of the equation.

In June, Local Motors unveiled Olli – a self-driving, 3-D printed electric mini-bus made with CFRP. According to Local Motors, Olli was born out of a contest the company held last year in Berlin. The winning entry from 24-year-old Colombian student Edgar Sarmiento became the basis for the design. Olli can carry up to 12 passengers and is the first self-driving vehicle to integrate the advanced cognitive computing capabilities of IBM Watson.

As the company explains, passengers can interact conversationally with Olli while traveling from point A to point B and ask questions about how the vehicle works, where they are going and why Olli is making specific driving decisions. Passengers can also ask for recommendations on places to go.

Local Motors says that up to a third of the vehicle was 3-D printed, including the shape that was used to create the mold for Olli. The CFRP used for the vehicle is 80 percent acrylonitrile butadiene styrene (ABS) and 20 percent chopped carbon fiber. In total, Olli weighs 3,300 pounds.

According to Charles Hill, an advanced materials engineer at Local Motors, the company turned to Oak Ridge National Laboratory and Cincinnati Incorporated’s Big Area Additive Manufacturing (BAAM) technology to create molds for thermal forming of ABS sheets for the interior panels of the bus. He says Local Motors produced 15 molds in about five days for two pilot program vehicles.

“That was one of the keys to this rapid development – to utilize this large-scale additive process to build the molds for vacuum thermal forming,” says Hill. He says that Olli features about 11 individual parts, including fenders, wheel wells, the front and rear panels, and interior kick panels, which were produced directly by large-scale 3-D printing using the same materials that the company used to make the 15 molds. Local Motors used the same process to make parts for the Strati, the world’s first 3-D printed vehicle, as well as its LM3D Swim, the world’s first 3-D printed car series.

Hill adds that Local Motors also used “more conventional composite parts” for about 10 body panels for the bus’s outside corners, roof panel and side panels. The continuous carbon fiber prepreg materials for those panels, which utilized an epoxy resin, were supplied by Roding Automobile in Germany.

Hill says the next step for Local Motors is to reduce the number of parts for the self-driving mini-bus and significantly reduce the assembly time required for future vehicles.

“We’re working right now … to further develop the large-scale 3-D printing, and we’re investigating a number of new materials to increase the mechanical properties of the 3-D printed parts,” says Hill. “In the future, we look to this process to be able
to build more of the vehicle directly with 3-D printing.”

Olli has been tested on public roads in Washington, D.C., and will soon be seen in Miami and Las Vegas. The mini-bus itself will be manufactured in microfactories in Phoenix and Knoxville, Tenn.

“We expect next year to have a new design that utilizes more composite parts,” says Hill. “[The current] design has a metal skeleton frame that we hope to replace, to some extent, with the more composite structure. We’re evaluating that right now and working on the engineering trades for composite structure versus metal structure, both the cost and manufacturability aspects of those.”

Advances in composite materials and technologies allow companies to push the envelope and create products that only a few years ago seemed impossible. One of those boundary-pushing companies is LM Wind Power, a Denmark-based supplier of rotor blades for wind turbines with manufacturing plants in eight countries. LM Wind Power has broken the world record for the longest wind blade three times: In 2004, it created a 61.5-meter blade and in 2011 a 73.5-meter blade. Earlier this year, LM Wind Power produced six prototype blades for Adwen, an offshore wind farm company. Each one measured 88.4 meters. That’s nearly 100 yards – almost the equivalent of a football field.

Engineers at LM Wind Power and Adwen spent months working on the design and integration of a blade for Adwen’s AD 8-180 wind turbine model, slated to have 8MW of nominal capacity and a 180-meter rotor diameter. But the companies aren’t simply seeking recognition in the Guinness Book of World Records. Larger wind turbines can produce greater – and greener – electricity.

Even for an experienced company like LM Wind Power, the project is challenging. “Everything becomes more complicated when working with such huge structures,” says Roel Schuring, vice president of engineering for LM Wind Power. “But the design is based on many years of experience in making wind turbine blades that provide the right balance between weight, length, strength and cost.”

Selecting the right composite material is key. LM Wind Power uses a combination of GFRP and CFRP, though it declined to provide details on the materials. “The hybrid technology is more cost-effective than full carbon blades and very robust in the manufacturing process,” says Schuring. “It reduces weight and static moment by up to 20 percent – two key vectors in blade design, enabling larger rotors to be fitted to the turbines to harvest...
three to six percent more annual energy production (AEP).”

LM Wind Power was able to produce the prototype blades using its standard manufacturing process, though it did develop new production equipment to handle such large blades. Schuring says the blades utilize a structural shell design with two blade shells and two webs manufactured individually. Fibers are laid up together with root bushings (metal inserts on which bolts are later mounted to connect the blade to the blade bearing), then they are infused, cured and inspected before blade assembly.

During assembly, the two shells are carefully bonded together with glue over a pair of webs. “The main laminate in the shells, together with the webs, comprise a box-like structure which gives the blades the required stiffness to withstand extreme wind loads without striking the tower,” says Schuring.

Two of the six prototype blades are now undergoing structural blade testing, including fatigue testing, in accordance with International Electrotechnical Commission (IEC) standards. One of the blades is at LM Wind Power’s full-scale test center in Lunderskov, Denmark, where the blades were built, and the other is 135 miles away in Aalborg.

Transporting such a huge blade was challenging, too – and caused quite a spectacle along the rural roads it traveled on June 30, 2016. A team of specialists accompanied the blade on its journey, temporarily dismantling any guardrails and sign posts when needed. The fully-loaded cargo was nearly 15 feet tall, leaving just over an inch of extra space when passing under bridges. It took more than six hours to move the blade to Aalborg.

Beginning in 2020, Adwen plans to install 62 AD 8-180 wind turbines off the coast of Saint-Brieuc, France, supplying electricity to more than 850,000 people.

The fiberglass and carbon fiber Elytra Filament Pavilion has been center stage at the Victoria and Albert Museum (the V&A) in London since May. Displayed in the John Madejski Garden until Nov. 6, 2016, the soaring 200-square-meter pavilion was commissioned as an exhibit of the historic art and design museum’s first-ever Engineering Session, highlighting the interaction of design, architecture and engineering in daily life.

Made of robotically-wound fiberglass and carbon fiber components, the pavilion weighs less than nine kilograms per square meter (or less than 20 pounds per square foot). Its name and structure are inspired by elytra – the stiff but lightweight forewings of beetles that protect the delicate hindwings used for flying. The project is the culmination of four years of groundbreaking research conducted by architect Achim Menges’ Institute of Computational Design (ICD) and structural engineer Jan Knippers’ Institute of Building Structures and Structural Design (ITKE), both at the University of Stuttgart, working in tandem with Moritz Dörstelmann and climate engineer Thomas Auer from Transsolar Climate Engineering and the Technical University of Munich.

“With the Elytra Filament Pavilion, we aim to celebrate a truly contemporary and integrative approach to design, engineering and production, resulting in a distinctive spatial and aesthetic experience,” says Menges. “Based on the biological structure of beetles’ hardened forewings, we have created a novel architectural system that is an intricate, extremely lightweight structure made entirely of glass and carbon fibers.”

The pavilion initially had seven supporting columns and 40 hexagonal canopy cells, which were fabricated over four months at the ICD’s Fabrication Hall in Stuttgart. The canopy utilizes a steel tool, while the load-bearing structure consists solely of fibers. The cells are made using a Kuka robot that winds resin-soaked filament onto a hexagonal winding tool. The robotic arm first winds transparent glass fibers onto the tool to form a spatial scaffold, then adds SGL Group’s Sigrafil® 50k carbon fibers to create the load-bearing structure. Once the matrix is hardened,
the steel tool is collapsed and removed so that it can be used again. “In contrast to most other composite fabrication processes, our innovative robotic winding process does not require any mold and thus reduces waste to a minimum,” says Menges.

Although produced on the same winding tool, each canopy cell has a unique fiber orientation, arrangement and density. “Despite the similarity in basic make-up, the robotic fabrication process enables an infinite range of morphological and structural permutations of the cells,” explains Menges. “The design, engineering and production of the pavilion’s fibrous system is based on a continuous feedback loop. As it is a fully digital process, each canopy cell can be adapted to its specific loading conditions.”

Each cell has aluminum sleeves embedded in its edges during fabrication. To assemble the canopy roof, bolts are passed through these sleeves and that of adjacent cells. The cells also are covered with a transparent polycarbonate panel with UV protection. Each finished cell weighs approximately 45 kilograms – or less than 100 pounds.

Perhaps the most compelling part of the Elytra Filament Pavilion is that it expanded on site, in real time, with five additional canopy cells fabricated at the V&A throughout the exhibition. Thermal imaging sensors embedded in the canopy collected anonymous data on how visitors use the pavilion. This information was then interpreted in conjunction with temperature, radiation, ambient humidity and wind data to help determine where additional canopy cells would be useful for weather protection.

“The pavilion showcases how research enables us to go beyond established modes of design and construction, resulting in a canopy that is as architecturally expressive as it is structurally efficient,” says Menges. “It provides the visitor with a unique spatial experience that transforms and evolves over time.”

Menges believes that the integration of design, engineering and fabrication – as well as the fully automated, reusable tool process that the pavilion showcases – will have many other applications, including lightweight, long-span building structures.
The cascade of silver panels that hang from the ceiling over Mercedes-Benz exhibits at American auto shows are dazzling. Lit by an array of lights, the rectangular bars shine as if they are metal. In fact, the panels are pultruded GFRP that have been designed to look like the solid aluminum bars used at a Mercedes-Benz exhibit at a European trade show in 2014.

The luxury automaker loved the overhanging display so much that it wanted something similar for all of its U.S. auto shows over the next five years. This created a dilemma. The original aluminum display was designed for one-time use and, though stunning, was too heavy to transport, set up and take down repeatedly.

Tasked with the job of replicating the exhibit for major U.S. auto shows, Dimensional Communications, Mahwah, N.J., brought the project to Strongwell to create a lighter, more durable version of the display from pultruded GFRP. To begin, Strongwell developed custom tooling. It took several months to create the tooling so that the end product would be strong enough to handle the rigor of set up and tear down over time, according to Barry Myers, marketing manager at Strongwell.

“It takes time to get tooling right,” he says. “Pultrusion dies are large, and generally they are steel and chrome plated. There’s a lot to them. So the turnaround time is a lot longer than making some less costly and complex dies.”

Once the tooling was ready, Strongwell fabricated 125 hollow GFRP panels measuring ⅛-inch thick, two inches tall and 16 inches wide. They are cut to lengths that vary from four to 20 feet. Strongwell used fiberglass rovings from Owens Corning and PPG and a continuous strand mat bathed in thermoset resins from Ashland and AOC. The panels also feature a polyester surface veil to provide a smooth and consistent surface.

Once completed, the panels were sent to Dimensional Communications, where GFRP end pieces were attached. Afterward, the panels were painted with an aluminum-look automotive quality finish. The finished panels, which debuted at the Los Angeles Auto Show in November 2014 “look like solid bars of aluminum, just as the originals did,” says Myers. However, they are much lighter than the
aluminum originals: For example, an aluminum 20-inch demonstration panel weighs 13.8 pounds, while a 20-inch GFRP one weighs 8 pounds.

“We’re looking at 58 percent of the weight of the aluminum,” Myers notes. “This was very important to reduce the cost of transport, to ease erection of the display and to hang the panels from various structures at the auto shows. The weight savings was a really, really big deal.” The GFRP panels can also be patched and repainted if they get damaged.

The display is a unique application for both pultrusion and Strongwell. “Most of the time, when you think of pultrusions you think of industrial applications,” says Myers. “It’s the first time that we’re aware of that pultruded FRP has been used to create a large sculpture or something of that nature. I think that speaks to the diversity of FRP in general and pultrusion in particular.” The striking panels have grabbed the attention of industry professionals, too, winning the Most Creative Application category in the Awards for Composites Excellence (ACE) competition at CAMX 2016.

“There is a great range of capability in the composites space,” concludes Myers. “The manufacturing method doesn’t need to put you in a particular box.”

Susan Keen Flynn is managing editor of Composites Manufacturing magazine. Email comments to sflynn@keenconcepts.net. Evan Milberg is communications coordinator for ACMA. Email comments to emilberg@acmanet.org. Melissa O’Leary is a freelance writer based in Cleveland. Email comments to mxh144@case.edu.
Suppliers of FRP pipes and tanks agree that the past year has been comparatively slow when it comes to new projects. Few of the major industrial manufacturers who so often demand composite-lined tanks or FRP pipes seem to be undertaking new construction, and in some market segments replacements are slow as well. But a number of indicators suggest that now is the time for fabricators to focus attention on educating end users across several industries about the benefits of FRP compared to alternative materials, as business stands poised to pick up.

A 2015 report from Research and Markets forecasts a modest 3.1 percent increase in the global FRP pipe market from 2015 to 2020. Demand in certain industries – including water/wastewater, chemical/industrial and onshore oil and gas – is expected to drive this growth.

For the optimistic, every challenge presents an opportunity. Fabricators facing the five challenges listed below may find themselves well-situated for opportunities in the coming year.

**CHALLENGE #1: Chemical M&A activity has slowed major construction.**

**OPPORTUNITY:** Need grows for pipe and tank maintenance and replacements.

“In the chemicals industry, everything has a lifespan,” says John Istre, quality control manager for Resin Systems Inc. in Sulpher, La. That holds true for the pipes currently serving chemical manufacturers. As a result, replacement work is an ongoing need.

In a recent presentation for NACE International, John Busel, vice president of ACMA’s Composites Growth Initiative, noted that in 2014, processing industries, including the chemical industry, saw a direct cost of corrosion as high as $67 billion. It’s one reason that many facilities seem to be focusing on repairs.

Tim Morton, production manager for FiberSystems in Dayton, Ohio, sees this emphasis on repairs versus new construction as a sign of the economic times. “We’re doing replacement fittings or pipes, and the same with tanks,” Morton says. “Not a whole lot of tanks fail, but I have a tremendous amount of work refurbishing tanks.”

For Istre, 2016 has been slow largely as a result of high turnover in the chemical industry. “One of the big things that’s been running the market right now has been the changing of the guard – companies buying out plants,” he says. In fact, A.T. Kearney, a global management consulting firm, notes in its 2016 Chemicals Executive M&A report that a number of megadeals have put 2016 on track as a record year for chemical mergers and acquisitions, potentially twice as high as already-high 2015 levels of activity.

The resulting challenge, Istre says, is that few companies are

A flexible riser for an offshore oil drilling platform is filament wound at GE Oil & Gas’ facility in Newcastle, United Kingdom.
spending money on additions or refurbishments as an air of uncertainty around future acquisitions continues. “But I think it’s going to settle down a little bit, back to almost normal,” he predicts.

With doubt about future ownership, many of these chemical companies have “let a lot of maintenance go,” Istre adds. As activity settles back to normal, new owners assessing their portfolio may be interested in pursuing infrastructure improvements in the year ahead. If this is the case, Morton predicts that there may be plenty of opportunity for smaller fabricators.

“We put the [down] economy, the big shops aren’t willing to set up special tooling to meet their customers’ [repair] needs. The customers are really in a jam, and that’s our niche,” Morton says.

**CHALLENGE #2:** Municipalities are unsure of solutions for failing pipes. **OPPORTUNITY:** Demand increased for corrosion-resistant piping for water infrastructure improvements.

It’s not every day that the pipe market finds itself in the news, but in the last year failing water systems have made pipe improvements very much a topic of discussion.

Busel notes that the drinking water, sewer treatment and sewer sectors saw direct costs of corrosion exceeding that of processing industries, coming in at $68 billion in 2014. One of the most talked-about failures came when the city of Flint, Mich., switched its water supply in 2014 to the Flint River. High levels of chloride, which reacted with high levels of bacteria in the river, ultimately corroded the city’s lead pipes. Subsequently, lead seeped into the drinking water supply, causing widespread lead poisoning. By the time the city returned to its original water supplier late in 2015, it was too late to reverse the damage to the pipes.

Flint may be the best known example of failing infrastructure, but it’s not the only one. In early 2016, a concrete water pipeline servicing Silicon Valley failed, leading to $20 million in repairs.

As a result of these failures, the U.S. Senate introduced the Water Resources Development Act of 2016 to authorize $9 billion in water infrastructure improvements, including $220 million specifically for Flint, Mich., and other cities that may have contaminated water supplies. The bill passed the U.S. Senate on September 15 on its way to the House. If signed into law, it promises to drive broad water and sewer infrastructure replacements, presenting opportunities for suppliers of corrosion-resistant FRP pipes.

“We promote FRP composite pipe for all water systems, but adoption of the material has been somewhat slow due to municipal budget restrictions,” Morton says. The availability of funding could help municipalities, although Morton notes that there are built-in savings with FRP piping. “FRP is a higher premium upfront, but the advantages quickly give customers a return on investment. Lighter weight reduces field installation costs, and corrosion resistance means minimal maintenance and a long service life. When you do the math, the savings counties can realize with FRP composites versus replacing pipe again and again are significant.”

Among other examples, officials in Dayton turned to FiberSystems for a composite solution when five packed tower aeration systems installed in the late 1980s began to fail. The aeration systems are used to eliminate volatile organic compounds from ground water. “The spools were experiencing early failure,” Morton explains. “In addition to being able to rebuild the damaged sections, we also significantly extended the lifecycle of the structures.”

Using a high-performance, high-temperature epoxy vinyl ester resin, the 12-inch diameter flanged reducing spools were filament wound and joined through adhesive welding. The spools were also coated with specialty UV-resistant polyurethane to provide the surfaces with corrosion resistance and protection for an improved cosmetic appearance.

There’s another area of water infrastructure that is leading to increased demand for FRP piping and tanks, too. “While not a new application, the increase in seawater and brackish water desalination in the Americas has contributed to the growth of FRP piping and tank use in this market segment,” says Chaun Trenary, vice president of marketing and sales for Denali Inc., a Houston-based manufacturer of FRP tanks, pipes and related equipment.

“We’re currently looking at several projects on the West Coast,” Morton says. “Large diameter, low-pressure FRP piping is best suited for above ground applications, but we’ve also provided continuous filament-wound FRP pipe and fittings for burial underground.”

**CHALLENGE #3:** Oil and gas industry hits new restrictions with move into more remote locations. **OPPORTUNITY:** FRP meets the pressure and weight needs of deep-sea applications.

The report from Research and Markets indicates that onshore oil and gas is expected to emerge as the leading FRP pipe market by value and volume consumption, after chemical/industrial applications. The growth of oil and gas exploration activities, coupled with a boom in shale gas production in the onshore oil and gas industry, is expected to spur growth for this segment.

Raymond Burke, product leader – flexible pipe, for Houston-based GE Oil & Gas, explains that given the massive cost of mounting an offshore drilling and construction campaign, oil companies concentrate on operating large, highly productive fields. This scale is pushing more wells into deeper and more remote locations. “One consequence of this trend is that floating production systems dominate new subsea developments, and flexible risers (the pipelines to hook the subsea production system up to floating platforms) become heavier as a consequence of depth,” Burke says.

He notes that the industry seems to have reached a challenging point between roughly 5,000 and 6,500 feet deep where the contradictory metrics of pressure resistance, combined with an operational need for larger diameter pipe, requires more steel. But more steel means more weight, which increases the axial force near the riser hang-off, which in turn requires more steel, Burke explains.

“Composite pipe resolves this technical tension by adding the optimal pressure resistance needed, without the associated weight penalty that traditional designs would incorporate,” he says. GE’s solution leaves the dynamic and highly-loaded components of flexible pipe unchanged. “Specifically, the tensile armor layers and the end fittings remain unchanged, allowing operators to retain
and leverage their existing knowledge and understanding of these products,” Burke says.

As he puts it, the challenge – and solution – is in making lighter, cheaper products that can reach deeper and safer than ever. And it is a significant challenge, given the tough environment. “Bear in mind just how critical the durability and robustness of these products is,” Burke says. “They will be installed into thousands of meters of turbulent seawater; attached to a highly dynamic platform; exposed to high pressures, wide temperature ranges, fluid surges, shut-downs and chemically aggressive well contents – and they are expected to function continuously, without intervention or maintenance for 20 or more years.” This means there is a very high qualification threshold, and a range of life-cycle and environmental testing must be completed and independently verified before a product can be operated subsea.

It was a challenge that FiberSystems had to address when tasked with modifying a positive break tank on a potable water system aboard the world’s deepest offshore oil drilling and production platform. Shell Exploration & Production contracted Jacobs Engineering to oversee the modifications for the offshore platform in the Gulf of Mexico. The tank needed to let out gases trapped in the service line and let in seawater that would pass through the water makers that would turn it into drinking water.
The tank needed to be corrosion-resistant, lightweight and low maintenance, which is what led the engineer to FRP.

“One of the problems we had to solve was how to anchor a freestanding pipe on the inside of the tank,” says Dave Orr, production supervisor for FiberSystems, the tank manufacturer. “Fabricating the tank’s cradle and determining the best method for adhering the top dome to the main body of the tank was also challenging.”

The main body of the tank, along with eight stubs and flanges, was filament wound using a high-performance grade of methacrylate epoxy resin pigmented gray. To meet a tight turnaround time, the fabricator used 113 yield fiberglass that allowed it to build tank walls up quickly – twice as fast as the thickest glass. The tank’s flat base and cradle also were filament wound. A hand lay-up process was used to fabricate the tank’s upper and lower domes, which were then bonded to the tank with adhesive.

Strength was paramount for this application. The joints were butt-welded and wrapped for added strength, and the fabricator used a resin wax coating to seal interior layups, the freestanding pipe inside the tank and the exposed openings. The final product weighed 1,000 pounds and measured 11 feet, 8 inches tall with a 30-inch inside diameter.

**CHALLENGE #4:**
Conservative companies are slow to adopt new solutions.

**OPPORTUNITY:**
Existing FRP solutions are poised to meet new demands.

Burke notes that customers appreciate seeing products that meet their needs for lightweighting and corrosion resistance without the associated risk of brand-new technology. Even so, fabricators are constantly watching for the next innovation. He cites several improvements in materials, including these:

- More robust polymers that can operate at higher temperatures and pressures
- Stronger fibers to withstand harsh environments
- Structural geometries and manufacturing methods to incorporate fibers and polymers in “unique and advantageous means,” such as pultrusion technologies
- Incorporation of additional functionality into the pipe structure, such as fiber monitoring for operational monitoring

“These are all of great interest to us as we contemplate the next generation of composite pipe for offshore oil and gas production,” Burke says.

Busel predicts that to better meet future demands in the chemicals and other processing industries, FRP fabricators will need to experiment with resins that can withstand higher temperatures.

In certain industries, a little experimentation can be a big risk, points out Dan Naugle, general manager for Composites USA in North East, Md. “Big companies like Honeywell, DuPont, Dow Chemical, etc., are pretty conservative in that they approve certain resins, in certain products, with certain processes. If it works for them, they don’t want to change it because they are getting into an unknown,” Naugle says.
In some cases, today’s needs can be met by taking a fresh look at how tried-and-true products can meet new applications. For example, Aram Mekjian, president of resin distributor Mektech Composites Inc. in Hillsdale, N.J., says that phenolic resins should be more closely considered in certain corrosive environments due to their heat-resistant properties.

“Phenolic resin is a little more difficult to use – it requires heat to cure – but the big advantage over any of the other resins is the far superior fire, smoke and smoke toxicity properties,” Mekjian says. “Also, it has very good high-temperature resistance.” He adds that phenolic ducting passes Factory Mutual (FM) requirements. “Other polymers would require water sprinklers inside the duct to reduce flame spread and heat release, which would cause failure,” he says.

Busel agrees that phenolic resins are a strong alternative for high-temperature applications. But, he adds, it all comes down to the application. “The debate goes on out there that fire-retardant resins are just as good as phenolics. Each has its own strengths,” he says.

“We use phenolic resins, which are very good for sulfuric and hot hydrochloric acid – very good for hot acids,” Istre says. “But they’re not very good for caustics, so we have to watch the application.”

And while the material does need to be processed differently than vinyl esters, Mekjian points out that even in the composites industry some misconceptions around phenolic processing may remain. “Some fabricators may still not know that phenolics can be processed via hand lay-up and filament winding,” he says. “Most still think phenolics are used in the form of prepreg used in autoclave.”

**CHALLENGE #5:**

**FRP is still an unknown for some markets.**

**OPPORTUNITY:**

Targeted education can lead to a new generation of end users.

For many conservative end users FRP is still a relatively new solution, at least compared to materials such as steel. As a result, customer education remains a critical business development tool.

“A lot of companies aren’t aware of what FRP can do,” says Naugle. “There are some companies that have always used steel tanks or piping that have come to us and said, ‘Show us the advantages.’” Naugle is quick to point out benefits, including FRP’s ability to create custom shapes. For example, during building rehabilitations new pipes often have to go around existing pipes and other structures. “You can’t do that with steel duct; It just can’t be formed that way,” Naugle tells customers.

“But with FRP, you can make custom pieces to fit in those areas.”

Trenary points out today’s up-and-coming engineers are entering the market with a greater understanding of composites and, as a result, greater willingness to evaluate the material’s merits for specific projects and products. They don’t simply default to metal or concrete with a cursory consideration of composites. “This shift, although a longer term development, will likely result in significant further acceptance and standardization in the FRP composite corrosion market,” he says.

Trenary finds the biggest challenge to growth for the corrosion-resistant FRP industry is its fragmentation. “While FRP has been successfully used in a wide range of markets for many decades, there still tends to be some significant differences among suppliers with regard to design practices and design capabilities,” he says. “In addition, it is often difficult for a customer or end user to identify a single published specification that they can rely upon for standardization.” For example, ASME RTP-1 is an FRP tank standard, but not all design variables allow use of the standard, says Trenary.

Morton adds that in some instances, end users view FRP as an exotic choice that will solve any problem, and that’s a challenge that demands more education as well. When FRP is misapplied, its failure can present problems for the industry.

“I had a customer call and ask for some piping that would haul sulfuric acid,” says Morton. “Unfortunately, FRP pipe is not the right material to use, although you can use an FRP tank to store sulfuric acid if it’s stored below ground because the ground acts like an insulator. So we find that there are still questions, and education needs to be given out there.” As Morton puts it, “Is FRP right for every job? No. But it’s right for a lot of them.”

And the possibilities are increasing. Now it’s up to FRP suppliers to educate end users on how composite pipes and tanks can be the best choice for them.

Megan Headley is a freelance writer based in Fredericksburg, Va. Email comments to rmheadley3@gmail.com.
Composites manufacturers today use surface finishes like gel coats and veils to improve their parts’ appearance and durability. But when their predecessors in the 1950s developed gel coats, they weren’t concerned about appearance. They were searching for a way to minimize the damage that fiberglass products were causing to their tools.

“Companies took the same type of resins that they used to manufacture glass fiber laminates, thickened them up, added filler, painted them on the mold and then made the parts,” says Rick Pauer, market manager at Polynt. “People started liking the look that the gel coat provided, so the next level was to give color or surface enhancements to the FRP parts.”

Boat builders saw the potential of gel coat and began asking manufacturers to incorporate other properties into it like ultraviolet (UV) and blister protection and water resistance. The marine industry is still the largest customer for gel coats, but manufacturers of transportation products (RVs, trucks and buses) and sanitary products (tub and shower surrounds) are also big purchasers.

For all of these markets, “the performance of a gel coat is very much about aesthetics; there’s protection to it, but a significant amount of it is appearance,” says Harry Certain, business manager, Interplastic Corp. “People are saying ‘I want my RV to look great 15 years from now; I want my boat to look brand new after a number of years.’”

Gel coats provide one big advantage over thinner coatings like paint. “Having a uniform color for 20 mils allows easy repairs to be made in a gel-coated surface,” says Pauer. “The agriculture, transportation and marine markets greatly appreciate the reparable of gel-coated composites where scratches and graffiti can be easily buffed back to their original surfaces. In the architectural market, the thicker gel coat is often sand blasted to provide a textured surface that looks much like concrete or terra-cotta stone.”

A Balancing Act

Producing a cost-effective gel coat is not an easy task. Scott Crump, technical director at Interplastic Corp., says that a typical gel coat formula contains between 15 and 25 different components. Change one ingredient to improve a particular property and you can adversely affect something else. “The challenge is trying to balance those ingredients and manage all the expectations of the fabricator and the end user, because there are always tradeoffs,” says Crump. “The things that give the coating a really good gloss retention are not necessarily the best things in terms of crack resistance. In fact, they go in opposite directions.”

The complexity of the task may be one reason why the number of gel coat manufacturers has shrunk from 20 at one time to four or five today.

“You look at the technology, at the economies of scale, you look at what it takes to be consistent and you can see it has gone from mom-and-pop operations to a more industrial design product in a plant,” says Crump. “When I first started, the company I was working for had literally started in a garage. They would not be able to do that today for a variety of reasons.”

Gel coat manufacturers have to design their products for both the immediate customer – the fabricator – as well as the end user. For fabricators, a gel coat has to produce consistent results. “It’s like paint, but it has to be able to be sprayed and it can’t run or drip,” Pauer says. That’s challenging with a material that usually runs 15 to 35 mils thick. In addition, gel coats must perform well over a range of temperatures, since some fabricators may not have good environmental controls in their shop.
“Porosity is also an issue,” Pauer adds. “We spray or paint this material on, but you can’t have any type of air voids because you could affect its continuous film characteristics. If there’s a hole in that file, if there’s porosity or a fish eye, that allows water to ingress and it looks like a defect on the surface. It also affects corrosion resistance, water resistance, the UV resistance — all of those things that you are using the gel coat for come into play.”

Gel coat formulations also vary by application method. Crump says that 90 percent of fabricators in the U.S. spray gel coats into the mold as the first layer of a composite part. “That really links the gel coat to the resin,” he says. “It becomes almost monolithic, because they are essentially bonded together. That’s one of the reasons that we use gel coats instead of just painting the outside of the surface with some other type of coating. It’s really durable because it’s not a physical bond to the surface, it’s a chemical bond.”

Composite product manufacturers apply the other 10 percent of gel coats post-finish. These surface coats add a thick, durable layer to a product’s surface.

Required drying time is another factor in gel coat formulation. One of Interplastic’s customers produces shower units at a high volume on a monorail system. “The gel coat has to be ready to laminate in less than 15 minutes. If it’s not, you’re slowing down the entire train,” Crump says. Boat builders, on the other hand, usually allow days or weeks for gel coats to dry.

**Designs for End Customers**

For owners of boats, RVs, tub surrounds and other end users, the priorities are durable gel coats that keep the desired high-gloss appearance for as long as possible. They don’t want to see blotchy colors or a chalky finish.

“The level of expectation has gone up; we’re making larger, more expensive, more high-end boats, and the customer wants them to retain that aesthetic as long as possible,” says Ryan Wilkins, North American marine gelcoat product manager, Ashland Inc.

Longevity is not the only end user requirement, however. “There’s adjustment and adaptation depending on where the product is going to be used,” says Certain. “For example, a transportation product doesn’t see as much water exposure as a marine product, so we can compromise a little on the water resistance but work very hard for UV resistance for that market.”

A cultured marble sink top with a gel coat finish won’t have problems with UV exposure, but will need to withstand thermal expansion and contraction caused by hot and cold water running over it. A wind blade on an energy-producing turbine may move at 300 mph, so its gel coat needs to have excellent abrasion and fatigue resistance as well as outdoor durability, including resistance to heat, light and moisture.

End customers have challenged gel coat manufacturers with their demands for a greater variety of colors with more depth and intensity. Black and other dark colors are popular with manufacturers of personal watercraft, for example, but developing the gel coats that maintain those colors over several years is difficult.

Style trends also impact gel coat formulations. Years ago, metal flake finishes were popular in the bass boat market; now, consumers want boats with a look that emulates today’s automotive finishes, which have very tiny flecks that reflect light.

When designing for the transportation industry, gel coat manufacturers have a different challenge. Truck rental and RV companies that use FRP wood panels for their vehicles’ sidewalls want the same color and finished look for the composite portions of their trucks as for the metal sections.

Some manufacturers design gel coats for smaller-scale products. Diversified Structural Composites, for example, produces the shafts for electric trolling motors for fishing boats.

“It’s a fiberglass-reinforced pultrusion that comes straight out of our die with a gloss, Class A finish,” says Rob Klawonn, company president. “We produce a very uniform, consistent surface finish for a low cost. We also add some UV inhibitors to the resin mix that gives it a long life as a composite outside; they can last 10 to 20 years in a rugged environment while maintaining a good surface finish without powdering or chalking.” A combination of processing techniques, resin chemistry and tool design enables the company to achieve this result, he says.

**Putting on the Veil**

Surface veils provide an extra layer of protection for composite parts. They are thin, lightweight materials weighing from 17 to 68 grams per square meter.

“With surface veils, we’re basically putting a fabric into the fiber manufacturing process to impart surface smoothness or to block the underlying reinforcements from blooming into the surface,” says Brandon Ratcliffe, business manager at Precision Fabrics Group. “You typically end up with a resin-rich surface layer, and as a result you generally enhance the corrosion properties of those composites. A lot of veils are used in corrosion-resistant pipes and corrosion-resistant tanks that hold aggressive assets and all kinds of corrosive agents.” Veils can also provide UV protection and fire resistance.

Veils fall into three major categories: glass, carbon and synthetic. Glass veils are common in everyday use because they process very easily and wet out well in the resin. They’re found in flooring and in corrosion-resistant products where the chemicals don’t attack the glass.

Composite manufacturers use carbon veils in niche applications, such as high-temperature caustic services or where the product needs electric static dissipation. “A lot of the FRP is highly insulated, and sometimes you have a chemical or a vapor that can build up a charge and you can have a fire hazard on your hands. So occasionally you will see carbon veil specified for you because you can ground that out,” Ratcliffe says.

Both glass and carbon veils must be compatible with the resin they’re going to be used in. That’s not the case with synthetic veils. “They are resin agnostic, so you can use them in any resin system,” Ratcliffe says. Synthetic veils provide better corrosion resistance when storing certain chemicals such as hydrofluoric acid and sodium hypochlorite, he adds.

Printed veil fabrics can provide graphic characteristics, such as a wood grain or camouflage look. Colored veils enable manufacturers to produce variations of their products without having to completely change over a line.

As with gel coats, a manufacturer’s decision on whether or not to use a veil often comes down to cost. “A lot of it is solving the
problem for the right price,” Ratcliffe says. “Imparting improved UV protection or putting in a layer that prevents a lot of smoke is a complex problem to solve and often requires a solution that is more than just a basic fabric. You have to put a coating on the veil, put in different absorbers or antioxidants for UV.”

Customers are looking for better solutions that they can integrate into their manufacturing processes in one fell swoop, Ratcliffe adds. However, they need to consider not just the upfront cost but the total cost of the process. A powder coat may be cheaper than a veil, for example, but the manufacturer may also end up with more scrap that can’t be reused.

Measured Advances

Progress in surface materials comes incrementally – an improvement in a gel coat’s resin can enhance durability, a new type of fabric can offer better corrosion resistance. But those changes make a real difference over time. One of Ashland’s earliest marina gel coats had an expected lifetime of 1,000 hours; its latest generation of products can reach 4,000 to 4,500 hours.

While surface coat manufacturers are reluctant to give specifics about the new products their companies are working on, they will discuss the industry’s direction in general terms.

“The drivers of change end up being cost performance, environmental performance or pure performance,” Crump says. One environmental driver has been reduction of the amount of styrene used to make gel coats; manufacturers had to redesign their formulas to get the same properties they had previously offered in the styrene-based formulas. Regulators are likely to continue the push toward lower styrene content and lower VOC materials in general.

Wilkins believes that product quality consistency will continue to be a major focus at Ashland and other gel coat providers. “There are a lot of inherent variations in gel coats, and that causes a lot of issues for manufacturers,” he says.

Interplastic has implemented some new quality and rheological controls that enable it to predict how a gel coat is going to spray, level and sag. “Those are the things that make for a much more pleasant experience for our customers,” says Crump. “They can spray the same way every time and it flows into the mold the same way every time.”

One relatively new development is a change in coloration methods. Color is usually part of the gel coat’s basic formulation, but Wilkins reports that a manufacturing plant in China now uses a neutral or white base gel coat and tints it on the assembly line. Ashland’s Instinct™ process, on the other hand, works much like mixing color into paints. It enables distributors to quickly add tint to produce the gel coat colors that their customers want.

While gel coat manufacturers work hard to meet the increased expectations of their largest customers, they are also looking for new opportunities. One potential market is construction. Diversified Structural Composites is already producing a garage door component with a Class A satin finish. Certain thinks the construction market could grow. “Gel coat is a pretty versatile material, and with some changes to its mechanical properties it might open up some opportunities,” he says. “Most of the gel coats out there today are designed to be very hard, high-gloss surfaces. But imagine that you had an in-mold coating that was more elastomeric. You could use it for other types of applications where you are not really looking for gloss or cosmetics, but for wearability.”

Gel coats could also play a role in 3-D printing technology. Polytnt is working with Oak Ridge National Laboratory, which produces molds for composite parts using a Big Area Additive Manufacturing (BAAM) printer. “With BAAM, they are putting down a very heavy bead of material,” says Pauer. “That leaves a very textured, corduroy surface on the mold.”

Researchers have been using a mill to grind off that rough surface, but Pauer thinks they could use gel coat instead. “You could under-print the part by ¼ or ½-inch thickness, then add a layer that bonds to the thermoplastic material, a material much easier to finish than carbon fiber-filled ABS. Then you can gel coat the mold.”

The gel coat layer would quickly provide the smooth, hard surface that the composite part makers require. That is, after all, what gel coats and other surface finishes do best.

Mary Lou Jay is a freelance writer based in Timonium, Md. Email comments to mljay@comcast.net.
Nearly 8,000 attendees flocked to this year’s CAMX – The Composites and Advanced Materials Expo and were excited and inspired by the growth and bright future of the industry.

The event reached new attendance milestones and offered a diverse conference program and exhibit hall. Industry professionals were motivated by the new CAMX Live! format during the opening General Session, where the audience heard 15-minute talks from visionaries Daniel Preston, CEO of Luminati Aerospace; Gregory Haye, general manager of Local Motors; and Greg Lynn, Prof. Arch. UCLA, CCO Piaggio Fast Forward & Greg Lynn FORM. They provided examples on how composites and advanced materials can be used in unconventional ways to make a positive impact on the world.

Some examples the panel highlighted included super

### CAMX 2016 by the Numbers

- **Approx. 8,000** Attendees
- **1,600** New attendees
- **50+** Countries in attendance
- **302,000** Square feet of exhibit space
lightweight and unmanned planes that deliver internet to areas without infrastructure, open source manufacturing technologies that produce 3-D printed vehicles and new ways to create housing materials that reduce shipping costs and environmental impact. The talks inspired the audience to think of using composite materials in new ways.

The exhibit hall provided another opportunity for the industry to showcase the full potential of composites. For three days, thousands explored the show floor with innovations impacting a wide range of markets, including automotive, marine, sports & recreation, transportation, aerospace, infrastructure and more. Recycling technologies, advances in 3-D printing, as well as innovative developments in aerospace, automotive and sports equipment were all on display.

Some of the most exciting exhibits included the uBox, an electric, urban utility concept vehicle, designed by Clemson University graduate students and displayed at Teijin’s booth. Another eye-catching item was a surfboard on display at Connora Technologies’ booth that was made with recyclable carbon fiber/epoxy composites. Many attendees also enjoyed watching Stratasys 3-D print parts at their booth. An application engineer at Stratasys said that many people stopped by during the beginning of a print, then came back later “like waiting on a pizza to cook.” Composites One with the Closed Mold Alliance and Magnum Venus Products also attracted crowds with their manufacturing demonstrations of closed mold processes. The demos covered parts for a wide range of applications, including marine, architecture, corrosion, aerospace and transportation.

The CAMX Award and ACE displays also featured some game-changing applications, such as the FRP cladding used on the San Francisco Museum of Modern Art and the first 100 percent digitally manufactured tools in an industrial autoclave setting.

In the spirit of novel ideas and innovation, the event also placed emphasis on young professionals. The event concluded with a lively panel of students passionate about the composites industry who envision a world where composites are as ubiquitous as pure plastics. They also offered insights on what they’re looking for from potential employers: an environment that fosters education and growth while promoting diversity.

For additional coverage of CAMX, visit CompositesManufacturingMagazine.com, and search “CAMX 2016” for these articles and more:

- Keynote Speakers Inspire CAMX Attendees to Innovate
- ACMA Recognizes Composites Excellence at CAMX 2016
- CAMX 2016 Demystifies Composites with Wide Range of Show Floor Innovation
- Can the Composites Industry Reach an 80 Percent Recycling Goal?
- Global Composites: New Opportunities, Disruptive Technologies and Going Green
ACMA at CAMX 2016

During CAMX, ACMA members worked together to shape industry direction, and to network and learn from each other at one of more than 30 meetings held during the week. ACMA also honored its members at the inaugural ACMA Membership Awards Ceremony & Reception the evening before CAMX officially kicked-off. More than 150 ACMA member company representatives came to support and celebrate with our four award winners. ACMA also worked toward attracting new members, as nearly 350 people visited the association’s booth and 25 prospective member companies were moved further along in their recruitment process.

From left: Mike Hood, Hood Manufacturing, Lifetime Achievement Award; Matt Chambers, Design Concepts/Marine Concepts, Hall of Fame Award; and Perry Bennett, Molded Fiber Glass, Outstanding Volunteer Award.

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Senate Bill Impacts Composites

The U.S. Senate passed the Water Resources Development Act of 2016 (WRDA), which takes steps toward promoting critical improvements to our nation’s water infrastructure. The Senate bill includes a provision from Sen. Sheldon Whitehouse (D-R.I.), which ACMA strongly supports, directing the Army Corps of Engineers to study the performance of composites in water resources projects and make recommendations on their ability to improve the performance of water infrastructure. ACMA encourages the U.S. House of Representatives to work with the Senate to send a comprehensive WRDA bill to President Obama for signature. ACMA encourages you to show support of this bill to your elected officials. For more on this topic, check out “Five Big Opportunities for Pipe and Tank Fabricators” on page 22.

Prop 65 Update

During meetings at CAMX, ACMA’s Regulatory Steering Committee (RSC) agreed on a program to help members comply with California’s Prop 65 toxicity warning regulation. The program will consist of three parts:
1. Test methods to quantify the potential styrene and styrene oxide off-gassing from composite products
2. A spreadsheet model to convert the

Meet ACMA in Indiana!

ACMA’s next Face-To-Face event will be December 7 in Elkhart, Ind. It is a great opportunity for members and prospective members to network with each other and meet with ACMA staff to learn more about the products and services ACMA offers, including the CCT program and local workforce development efforts. For more information, contact Paul Hirsh at phirsh@acmanet.org.

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3. A compliance decision flowchart that will help companies use the exposure estimates to inform their compliance decisions

A preliminary Prop 65 toolkit is also available to members at www.acmanet.org/prop65.

ACMA to Form Thermoplastics Committee

A group of companies involved in thermoplastic composites, including resin suppliers, fiber suppliers, product manufacturers, consultants and academics, has agreed to organize under the ACMA umbrella. The committee’s objective will be to promote and expand the use of thermoplastic composites.

New Members

City College of New York
New York, N.Y.

Enterprise State Community College
Enterprise, Ala.

Luna Innovations, Inc.
Roanoke, Va.

Stephan Wood Products
Grayling, Mich.

UTComp, Inc.
Cambridge, Ontario, Canada

For more information on becoming a member of ACMA, email membership@acmanet.org or call 703-525-0511.

Upcoming Events

November 29 - December 1, 2016
ACMA Exhibits at COMPOSITES EUROPE
Dusseldorf, Germany

January 11-12, 2017
ACMA’s Composites Executive Forum
Washington, D.C.

April 4-5, 2017
Pultrusion Conference
Atlanta, Ga.

September 11-14, 2017
CAMX 2017
Orlando, Fla.

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Trending on CM’s Industry Digest

Industry Digest is a weekly e-newsletter that delivers the latest news in the composites industry. Below are recent Industry Digest stories that people are reading:

**World’s Largest 3-D Printed Item:** Using Big Area Additive Manufacturing (BAAM), researchers at Oak Ridge National Laboratory created the world’s largest 3-D printed item: a trim- and-drill tool for the Boeing 777X.

**SpaceX CFRP Ship for Mars:** SpaceX CEO Elon Musk announced the company plans to travel to and possibly colonize Mars in a spaceship made with carbon fiber composites.

**World’s Largest Trimaran:** Latitude Yachts’ futuristic, all-composite 174-foot multihull trimaran known as the “Galaxy of Happiness” debuted at the Monaco Yacht Show. The yacht is the largest trimaran in the world.

**Automotive Carbon Fiber Market:** According to a report from IHS Markit, entitled IHS Chemical Carbon Fibres, Chemical Economics Handbook, the usage of carbon fiber in automotive manufacturing is expected to nearly double from 2015 to 2020.

To receive stories like these in your inbox every week, get your free subscription to Industry Digest by going to myacma.acmanet.org/nf/news. You can also check out the column at compositesmanufacturingmagazine.com/category/columns/industry-digest/.

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Known bondholder, Mortgagees and other Security Holders owning or Holding 1% or more of total Amount of bonds, Mortgages or other Securities: None. Tax Status (for completion by nonprofit organizations authorized to mail at special rates): Has not changed during preceding 12 months. Publication Name: Composites Manufacturing. Issue Date for Circulation Data: Sept. 1, 2016.

Extent and Nature of Circulation; Average No. of Copies Each Issue During Preceding 12 Months; Actual No. Copies of Single Issue Published Nearest to Filing Date: Total No. of Copies (net press run): 7853; 9784. Paid and/or Requested Circulation: (1) Paid or Requested outside County Mail Subscriptions Stated on Form 3541 (include advertiser’s proof and exchange copies): 7390; 8750. (3) Sales through Dealers and Carriers, Street Vendors and Counter Sales and other Non-USPS Paid Distribution: 200; 200. Total Paid and/or Requested Circulation: 7590; 8950. Non-requested Distribution: (1) Outside County Nonrequested Copies Stated on PS Form 3541: 211; 210 (4) Nonrequested Copies Distributed Outside the Mail: 40; 590. Total Nonrequested Distribution: 251; 800. Total Distribution (sum of 15c and e): 7841; 9750. Copies Not Distributed: 30; 50. Total (sum of 15f and g): 7871; 9800. Percent Paid and/or Requested Circulation (15c/15f x 100): 97%; 92%.

This Statement of ownership will be printed in the November/December 2016 issue of this publication.

I certify that the statements made by me above are correct and complete. Signature and title of Editor, Publisher, business Manager or owner: Thomas Dobbins, Oct. 1, 2016

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