A Report on the Rail Industry

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Features

Composites Are on the Fast Track ............... 9
Composites use in the railroad industry is on the rise for applications ranging from train car doors to interior seating and station platforms.
By Megan Headley

From Concepts to Composites ................. 14
Our annual coverage of university research and development highlights five innovative projects from across the country that may change the industry.
By Susan Keen Flynn and Melissa O’Leary

Simulations Speed Development .......... 21
Advances in simulation and modeling technology allow companies to design increasingly complex composite products. But there’s more work to be done.
By Mary Lou Jay

Second Nature .................................. 25
Get to know Kevin Barnett, ACMA’s incoming Chairman of the Board of Directors and CEO of Core Molding Technologies in Columbus, Ohio.
By Evan Milberg

About the Cover: A BOMBARDIER ELECTROSTAR electric multiple unit, South Africa
Photo Courtesy of Bombardier Transportation
From the ACMA Chair

The Research Driving Our Industry’s Future

I am honored to begin my two-year tenure as Chairman of the ACMA Board of Directors. As you know, the composites industry is growing at a rapid pace, and I’m excited to work with everyone at ACMA to help our members flourish through robust and innovative programs that move the industry forward.

Some of the greatest innovations that help the composites industry grow come through research and development. Last year, our team at Core Molding Technologies completed the development of our Hydrilite™ sheet molding compound (SMC), which has a specific gravity lighter than water. The material weighs 50 percent less than standard-density SMC while maintaining the required properties and can be used for a wide range of lightweighting applications. At first, we weren’t sure that achieving such a low density was possible, but by looking at a standard problem through a different lens, we were able to find a solution meeting our objectives.

The challenges end users face, whether it is weight reduction, corrosion or something else, become an opportunity for our industry. Others in our industry have similar success stories that demonstrate the vibrant progress of our industry and the role technology and collaboration play.

Great research and development is happening at the university level as well. At ACMA, we have a dedicated Technical Committee working to help members foster relationships with universities and understand how research can impact their products.

Our lead story (page 14) in this issue of Composites Manufacturing highlights a number of cutting-edge innovations that could change the way the world views composites. Thanks to collaborations between businesses and academia, our industry is finding innovative ways to join dissimilar materials, protect astronauts on Mars, turn coal into carbon fiber and much more.

Continued advances in R&D give each of us a leg up on our competition against traditional materials. In addition to university research, this issue takes a broad look at the challenges competing materials face in the automotive market and what leaders in those industries are doing to address them. (Article on page 4.)

Through informative articles like these, as well as our market development efforts through the CGI program, ACMA will continue to provide the most relevant information you need to grow your business.

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CONGRATULATIONS TO THIS YEAR’S ACMA AWARDS RECIPIENTS

These awards recognize the exceptional people who have done their part in making the field of composites a great industry.

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*Western Carolina University*

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Spotlight on Competitive Materials

The global automotive composites market is anticipated to reach nearly $15 billion in 2018, according to online statistics company Statista Inc. That certainly seems like a lot. However, composites only represent about 1 percent of all materials used in light vehicle production, according to consultancy Industrial Market Insight. Other materials vying for the attention of automakers include high-strength steel and aluminum.

At the Advanced Design & Manufacturing (ADM) conference in Cleveland earlier this year, speakers in the automotive track discussed material innovations that will contribute to lightweighting, including CFRP. The November/December issue of Composites Manufacturing magazine will include a full-length feature article on composites in the automotive market. So rather than highlight composites here, we opted to take a look at what those pitching competitive materials – in particular, high-strength steel (HSS) and aluminum – have to say.

Highlights of HSS

“When you think about lightweighting in automotive, steel isn’t always on the list,” said Jody Hall, vice president of the automotive market for the Steel Development Institute, in her presentation at ADM. “I’m here to talk to you about why it’s not only on the list, but it’s at the top of the list for many applications in automotive, especially for body structures.”

Hall provided attendees a quick history lesson on innovation in steel sheet materials, beginning with the launch of HSS in the 1980s. Today, there are more than 200 grades of steel,
with innovations in the past decade focused on high-strength, highly formable materials. Twinning-induced plasticity (TWIP) steels have become popular in automotive because of their excellent mechanical properties, high energy absorption and high stiffness. However, admitted Hall, TWIP steels are heavily alloyed, a bit more expensive and difficult to join.

Hall indicated that the steel industry is currently working on the “gap area” in its third-generation materials. “Now that we have the third generation of advanced high-strength steel, we need to deliver more cost-effective steels than the TWIPs, but also provide great ductility along with high strength.”

The Steel Market Development Institute is part of a consortium called the Auto/Steel Partnership that has several initiatives to improve the quality of steel and stamped components. Much of the focus is on enabling manufacturing. “Automakers are very confident they know how to design with the material, but manufacturing is an issue,” said Hall. “They need to be able to stamp these parts and join them together to make a good structure.” Some of the consortium’s main projects focus on body stamping, tooling, simulation to optimize formability, reparability and chassis work. (Learn more about the projects at www.a-sp.org.)

“Advanced high-strength steel is the fastest growing material on a vehicle,” said Hall. “We are actually replacing ourselves – mild steel and high-strength, low-alloy steel – with high-strength steel so we can reduce the mass of a vehicle.”

She called steel the “first choice” for automakers, but acknowledged that other materials are gaining ground. “Steel is the most cost-effective, and [automakers’] infrastructure is set up for steel, so they try to use it first to hit performance targets and mass reduction,” said Hall. “But if they can’t do it with steel, they’ll work with other materials.” Materials like CFRP.

**A Look at Aluminum**

Henry Bertolini, technical director at Pennex Aluminum Co., began his presentation at ADM by admitting one of the challenges for aluminum: “How do we improve our strength and not go up in cost?” he asked. That’s a concern shared by CFRP suppliers and one that hinders both aluminum and composites from gaining more market share in the automotive sector.

“Only 2 percent of a vehicle’s mass is aluminum structure,” said Bertolini. “The low-hanging fruit has been harvested. Taking simple parts and converting them to aluminum has been done for quite a while. Now the hard part has to be done: We have to design for aluminum.”

Bertolini cites the Cadillac CT6, which debuted in 2016, as an example. The body of the mixed-material luxury sedan is 64 percent aluminum and weighs approximately 200 pounds less than a similar size vehicle using predominantly steel. The structure also uses less parts. For example, the front-door hinge pillars feature 13 high-pressure aluminum die castings, each one replacing 35 steel stampings, according to *Motor Trends* magazine.

The aluminum industry hopes to gain traction with customers by touting...
its benefits: short production lead times, low tooling costs, recyclability and the ease with which it can be fabricated into integral shapes. But aluminum faces significant hurdles, many of which will sound familiar to composites professionals. The first is convincing automakers to design for aluminum, rather than simply replace steel components.

Bertolini shared the story of an OEM that asked Pennex Aluminum to convert a steel chassis to an aluminum one. Afterward, the automaker complained that the chassis was still too heavy and it was expensive. “We told the OEM, ‘You must focus on the design point. You have to start over, design for aluminum and take advantage of the geometry,’” said Bertolini. In addition, automakers will need to change their manufacturing processes to integrate aluminum into the assembly line.

Another hurdle involves the supply of highly-engineered alloys. Bertolini said Tesla pushed the envelope with new alloys, which worked great when the company was building fewer cars. But demand for aluminum skyrocketed for the Tesla Model 3, he said. “We don’t have enough industry capability to provide this exotic material at the required tolerances,” said Bertolini. So Tesla opted for more common alloys to expand its supplier base. “That’s a challenge for the extrusion industry – to bring the tide up so more people can supply more highly-engineered products,” said Bertolini. (For more on aluminum, check out the Aluminum Extruders Council’s website at www.aec.org.)

For now, material selection is often about trade-offs, said Bertolini. OEMs want the ultimate in high strength, the closest tolerances available and the best crash performance. “I tell them to pick two,” said Bertolini. “But that’s what the customer wants, and to move forward we need to learn how to do all three and balance them properly to give the best performance for the dollar and the pound.”

It’s a challenge faced by all material suppliers. “The reality is if we don’t do it on the aluminum side, the automakers will walk over to the next guy and say, ‘What are you going to do for me?’” said Bertolini. “And if the next guy is CFRP or magnesium, then the automakers will get on that horse and ride it. The OEMs are material neutral, as long as it does what they want and it’s cost effective.”

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

For more stories like this, visit CompositesManufacturingMagazine.com and check out the Automotive articles under the “Market Segments” tab.

More than 72 percent of the cab structure of the 2015 Chevrolet Colorado comprises advanced HSS, according to Jody Hall, vice president of the automotive market for the Steel Development Institute. The center pillar is made with one piece of press hardened Martensitic steel that’s thinner on the top and bottom than in the middle to optimize performance. “They don’t need as much mass in the top and bottom, so there’s less material there,” says Hall. “And in today’s market, every gram counts.”
If you’ve spent time on a U.S. highway at any point in the past 30 years, you’ve seen a Wabash National semi-trailer. The company is the largest semi-trailer producer in North America, manufacturing more than 60,000 semi-trailers last year. But while the company is firmly established as an industry leader, president and COO Brent Yeagy has never been complacent. Four years ago, he implored senior leadership to look to the future to overcome its products’ performance barriers and improve the design of its semi-trailers.

The result was the transportation industry’s first refrigerated trailer made with molded structural composites. Three months ago, Wabash announced it would begin a limited production run of 100 units over 18 months. According to Robert Lane, Wabash’s vice president of product engineering, the reaction to a 2016 concept trailer was so positive that the company acquired some early customers before it even built a prototype. They include transportation providers K&B Transportation, Werner Enterprises, Leonard’s Express and Combined Transport.

Wabash was first introduced to the possibility of using composites in the trailer by Structural Composites, a Melbourne, Fla.-based company that was using unique composite technology for shock-mitigating Navy boats. Wabash assessed performance and economic metrics, then benchmarked how the technology might apply to trailers.

Wabash opted to use composites, however the project came with a steep learning curve for everyone involved. “We had a lot to learn about semi-trailers and refrigerated truck bodies and what kind of loads they go through,” says Scott Lewit, president of Structural Composites. “And they had to learn from us about what composites can do.” Yeagy encouraged the team to push the boundaries and not be afraid to fail, recalls Lewit. “This approach allowed us to learn and innovate from failure and to rapidly develop and deploy new technology,” he says.

By incorporating molded structural composites instead of aluminum, Wabash improved the trailer’s overall thermal performance by up to 25 percent.”
Wabash used Structural Composites’ PRISMA® as the main material for the trailer’s entire box, which consists of the roof, walls, nose and floor. It provides excellent insulation qualities at a lower weight than conventional sandwich materials and has the necessary scalability to service a large market, says Lewit. CFRP can also be selectively utilized in the trailer to further reduce weight.

Wabash utilized a combination of unidirectional and other orthotropic configurations of glass fiber. The company combines the PRISMA preform elements with several different resin combinations depending on the size and specifications of each part. Some parts feature vinyl ester resin, while others incorporate polyester or Structural Composites’ proprietary CoCure resin.

In addition to PRISMA, Wabash used Structural Composites’ CoCure strain tunable coating technology for the trailer’s interior and exterior wall, roof surfaces and interior floor. The technology allows polyester resins and coatings to be combined with polyurethanes on the factory floor. The strain tuning aspect refers to the ability to change the urethane blend ratio, thereby altering the resin properties – in particular, the strain to failure.

Wabash and Structural Composites also developed a method that allows direct lamination of metals. The CoCure Hybrid Metal technology improved performance, reduced cost and was rapidly advanced from the lab to deployment on road-qualified trailers, according to Lewit.

Lane adds that Wabash experimented with vacuum infusion and RTM for the composite parts. The floors of the trailer were open molded, and the walls were closed molded. Lane says that in the long term though, the company is leaning toward making more of the trailer’s big parts through closed molding because it will be more environmentally friendly and lead to better part consistency and output.

By incorporating molded structural composites instead of aluminum, Wabash improved the trailer’s overall thermal performance by up to 25 percent. The trailer’s floor is also up to 20 percent lighter than it would be with steel, and the system is far more puncture- and damage-resistant than conventional constructions. In addition, the company indicates that using molded structural composites for the floor system means the trailer can handle more weight – up to 24,000 pounds – compared to conventional refrigerated vans that are rated for up to 16,000 pounds.

For Wabash, all of those advantages translate to a financially-viable solution. Lane says that one of the biggest barriers to the integration of composites in the trailer industry has been cost. Many resins are cost-effective but suffer from poor mechanical properties. Structural Composites’ PRISMA and CoCure technologies give Wabash scalable technology that provides great performance at an affordable price.

The properties of the trailer, in turn, mean increased savings for Wabash’s customers. “When we talk about improving the thermal performance of a refrigerated trailer, that means real dollars to the customer because they’ll use less fuel if it’s more thermally efficient,” says Lane.

He adds that customers are also attracted to the possibility of hauling less weight down the road, which also leads to greater fuel efficiency. Lane explains that the federal highway system in the U.S. mandates the weight of a trailer, tractor and payload cannot exceed 80,000 pounds. “So if they’re already hitting that 80,000-pound limit and we give them 20 percent lighter weight in the trailer, then they can put more freight in the trailer,” Lane explains.

While excitement abounds in the transportation and composites industries, Wabash is starting small so it can focus on documenting performance in real-world applications. Ultimately, Lane says everything is going according to schedule. As of May, Wabash had one trailer on the road and another in production. The company also has 20 truck bodies on the road and performing as expected.

Evan Milberg is communications coordinator for ACMA. Email comments to emilberg@acmanet.org.

For more stories like this, visit CompositesManufacturingMagazine.com and check out the Infrastructure articles under the “Market Segments” tab.
The trackside walkway at London’s Ferme Park railyard features Dura Grating, GFRP grating from Dura Composites that allows for water drainage and the passing of small debris while the trains are cleaned.

The global rail industry seeks innovative solutions to make train travel more reliable, comfortable and cost-effective.

By Megan Headley
D

espite its storied history, rail is rarely the first choice for speedy travel these days in the U.S. Yet for developed countries seeking solutions to worsening congestion resulting from urban sprawl and developing nations working to connect rural communities to distant cities, trains are an increasingly attractive solution for long commutes. The result is that rail stakeholders are looking for new solutions to improve the industry’s greatest challenges.

“It’s long been acknowledged that the challenges facing Britain’s railway network are those of capacity, reliability and efficiency, and that new technology holds the key to solving many of these,” says Tom Bowman, commercial director at Dura Composites, a U.K.-based manufacturer.

These challenges are not unique to Great Britain. From China to the United States and elsewhere around the world, train manufacturers, railroad associations and governments are striving to better connect communities by improving rail infrastructure, reducing the costs of high-speed and local rail systems, and creating comfortable and reliable trains that people will be eager to use.

Budgets that are “under ever increasing scrutiny” represent another big challenge that stakeholders face, according to Bowman. “It’s never been more vital to ensure that the solutions provided to the rail industry are both future-proof and have a measurable impact on efficiency.”

It’s no wonder that composite materials are viewed as a key solution.

Building a More Efficient Train

According to a February 2017 report from market research firm Lucintel, the future of the global rail composites market looks promising, with opportunities in both interior and exterior applications. The report projects the market for composite applications in the global rail industry to reach an estimated $821 million by 2021, growing at a compound annual growth rate of 3.6 percent. Major drivers for this growth include increasing demand for lightweight materials and rapid development of high-speed trains.

“Composites fit in very well with the lightweighting agenda,” says Ajay Kapadia, knowledge transfer manager for advanced composites at the Knowledge Transfer Network, a company that connects innovators with funding support. The cost benefits of reducing the weight of train cars are a key driver for the growing use of composites in many applications.

“Obviously, cost is the main issue – the cost of power and the cost of maintenance,” Kapadia says. As he points out, lighter trains allow for increased capacity. “With urban areas becoming more populous, especially in the developing world, they need a rapid transit system that fits in more people.”

Nowhere is this truer than in China, where the country is pouring more than $500 billion into its rail infrastructure by 2020 to improve connectivity. A Bloomberg News report released in December 2016 explains that the high-speed rail network will span more than 18,650 miles, cover 80 percent of the country’s major cities and boost economic growth by connecting people in rural communities to urban jobs. This announcement came at a time when China already holds the world’s longest network of high-speed trains, with more than 12,400 miles of route in service.

This rapid growth presents a big opportunity for train car manufacturers and composite companies, such as Aliancys. The Swiss company has supplied Chinese train manufacturers like Changchun Lu Tong Rail Vehicle Co. Ltd, with fire-retardant resin systems for non-structural train components, including front exterior trim, interior walls and components, and integrated sanitary units, all certified to relevant standards. The use of fire-resistant composite components has gained exposure, garnering interest in recent years in the possibility of replacing metal structural components with CFRP.

However, Kapadia says that the rail industry remains hesitant to integrate composites into structural applications just yet. “For anything that carries load – like the main structure of the train – they’re reluctant to use composites because of the fire risk,” he says. The issue surrounding fire, he adds, is not that the train shouldn’t burn, but it should not start burning before people can get out. “So even if you have a metal train – and most trains are made out of aluminum these days – that will still burn. But you have some time to get passengers off the train before that starts to happen.”

Instead, Kapadia suggests that manufacturers continue to push the boundaries for the use of composites in interior products. By getting new resins and technologies into these applications, they’ll be able to point to successful examples over time that will build the case for more widespread use.

“It think we’re going to see continued use on secondary structures and interior structures, and that’s going to build confidence for greater use of composites,” Kapadia says. “If a train operator says, ‘We’re looking at a composite door here; it’s been working for 20 years, we’ve had a fire, and it did fine,’ that confidence buildup with the train operators and the train manufacturers will be key to greater use of composites in the rail industry.”

Remaking Train Interiors

Forecasters agree that train interiors are the area to watch for new uses of composites. Lucintel predicts that the interior segment will remain the largest market segment by volume, with growth driven by the increase of options in fire-retardant materials with improved aesthetic properties.

Because fire resistance remains an issue for broader use,
Kapadia sees resin suppliers exploring the use of next-generation fire-resistant resins. For example, the global chemical company Scott Bader teamed with Shanghai Cedar Composites Technology Co. Ltd. to provide luxury cabin chairs for high-speed trains operated by China Railway, the national railway operator. The CFRP chairs, produced via vacuum assisted resin transfer molding (VARTM), feature Scott Bader’s Crestapol® 1212, a low-viscosity, fire-retardant urethane acrylate closed mold resin. The resin meets several international performance standards, including Germany’s DIN-5510 fire test for railway components, France’s NFF 16-101-F0 fire test for railway components and NFP 92-501-M1 building materials combustion test, and the European Commission’s EN/TS 45545-2: 2009 on fire testing materials and components for trains.

In addition to fire-resistance, cost remains another issue that composite suppliers need to address. “You have to balance the upfront costs with the ongoing costs,” Kapadia says. “If something costs a little bit more upfront but saves you money throughout its life – because composites don’t corrode, they’re lighter so they save you on fuel, etc. – that is an equation that people are increasingly going to consider.”

**Opening Doors to Innovation**

Achieving cost savings by providing lighter weight components was top of mind for U.K.-based Penso Group when it unveiled its CFRP train door last year. The press-formed phenolic prepreg door, with an integrated core sandwich panel, reportedly provides a 30 percent reduction in weight compared to standard aluminum doors.

Train doors are a critical area in need of innovation, according to Shift2Rail, a European initiative supporting improved trains and more durable and cost-effective rail infrastructure. The group encourages the development of doors that move away from current solutions based on honeycomb, aluminum or steel sheets, which have drawbacks around energy consumption, as well as noise and thermal transmission.

The organization is pushing manufacturers to use composites as the foundation of train door systems that open and close more quickly than today’s systems, while meeting necessary safety and reliability levels. An uptick in door speed could reduce people’s time spent on the platform and increase overall line capacity.

Penso reports that by using processes such as hot compression molding and high-pressure resin transfer molding (HP-RTM), the company is able to achieve process cycle times of four to 15 minutes, respectively. This production speed is key to making the use of CFRP more competitive against traditional materials. The company has recently invested in a new plant and equipment with support from Great Britain’s recently launched Rail Supply Growth Fund aimed at helping businesses grow their capabilities and capacity to meet need in the expanding rail supply sector.

**Improving Outdated Infrastructure**

Many countries are also finding that composites can help lead the wide-scale infrastructure improvements necessary in the

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rail industry. And there’s much work that needs to be done. Consider, for example, that the U.S. rail network is comprised of nearly 140,000 miles of track and more than 100,000 bridges. The 2017 Infrastructure Report Card issued by the American Society of Civil Engineers noted that the average age of major Northeast Corridor backlog projects – those between Boston and Washington D.C. that require upgrade and repair – is 111 years old. Everything on this list from tracks to moveable bridges is overdue for an overhaul.

In the meantime, routine maintenance of aging infrastructure is critical. Network Rail, the owner of Great Britain’s rail infrastructure, conducts approximately 10,500 annual inspections of the timber and steel structures buried in ballast (gravel that forms the bed of a railroad track), concrete or other materials to ascertain their condition without damaging the structure itself or disrupting rail services. Using an easy-to-remove composite grating to cover the timber and steel structures can make such inspections quicker and less expensive, according to Dura Composites.

Typically, conducting track maintenance requires downtime when trains don’t run. As a result, infrastructure solutions that last longer than traditional products – or eliminate downtime altogether – can lead to significant cost savings for rail systems. Maintenance costs can also be reduced by using lightweight composite solutions for applications such as station platforms rather than concrete ones that require heavy machinery to lift materials on and off site.

As Bowman points out, “The lightweight, high-strength and non-conductive nature of composite materials and their ease of handling allows for work to be carried out at difficult locations where a more traditional approach would be a logistical nightmare.”

Ferme Park railyard in London replaced its concrete troughs along the trackside walkway with Dura Slab GFRP duct cover. By using 43-millimeter Dura Slab Light, consisting of a 38-millimeter thick grating with a 5-millimeter solid top, the railyard was able to protect service equipment with a cable trough covering that could be easily removed for rapid maintenance. Dura Composites says its GRFP solution was chosen because traditional concrete troughs have a tendency to suffer from corrosion and sporadic failures, rendering them unsafe.

The company’s Dura Platform provides a similar solution for station platform maintenance. The pultruded GFRP platform, utilizing various grades of polyester, vinyl ester and proprietary resins, was developed in compliance with standards set by Network Rail to rapidly replace or overlay damaged platforms in modular sections. For example, more than 2,500 square feet of concrete platform at Needham Market train station in England was replaced with Dura Platform in only 36 hours.

“Habitually, these types of platform projects take eight to
10 weeks to complete using traditional materials,” Bowman says. And according to the company, the composite platform replacements can be performed at similar or lower overall costs than concrete.

**Overcoming Common Challenges**

“We are definitely seeing a huge increase in the use of GRP for the rail industry, both in the U.K. and overseas, thanks to its compelling lifecycle cost and overall versatility,” Bowman says. However, there are still hurdles to broader growth.

“The use of composites requires a change of mindset for some customers who have traditionally used concrete and may not be aware of the benefits of composites,” says Bowman. For example, there’s a perception among some rail operators that GFRP is not as strong as concrete, while in reality it offers an incredible strength-to-weight ratio, he says.

Companies like Dura Composites continue to develop new materials and technologies to increase the potential strength and cost efficiency. “We are exploring the use of hemp instead of glass due to its improved environmental impact, product strength and natural resin compounds,” Bowman says.

But perhaps the biggest challenge related to composite materials is the initial cost. “It can be higher for composites than for some traditional materials thanks to their highly-engineered composition,” says Bowman. “However, GRP products compete very favorably on a performance/life cycle cost basis versus traditional materials.” When rail owners factor in high initial costs of installation – for example, the costs of using cranes to lift concrete trench covers or the cost of equipment to remove concrete components for routine inspections – then composite products become much more competitive with traditional materials.

These cost arguments may prove critical in moving composites into broader infrastructure applications, as funding is a challenge for improvements in many countries. For example, a May 2017 poll of Californians performed by J. Wallin Opinion Research found that only 12 percent of voters want to maintain their financial commitment to the nation’s first high-speed rail project as its projected cost has ballooned from $40 billion to $64 billion. And a 2015 study by the European Parliament on railway infrastructure financing concluded that the European Union’s railway policy “is a long-term challenge” due to fragmentation of railway systems, their poor conditions in many regions and varying levels of investment support from member countries.

But ground-up projects such as California’s high-speed rail are exactly where composite materials can do the most good in reducing long-term maintenance and providing a more cost-effective ride. It’s up to the composites industry to make its case before outdated infrastructure that’s too expensive to improve upon makes the railroad a treasure of the past.

Megan Headley is a freelance writer based in Fredericksburg, Va. Email comments to rmheadley3@gmail.com.
School may be out for the summer, but researchers at universities across the country are still hard at work on projects to advance composites. This year’s annual article on university research and development presents five projects highlighting a wide scope of investigations. They range from materials development (turning coal into carbon fiber) to processing advancements (joining in the automotive sector) and cutting-edge applications (a space suit for travel to Mars). So sit back and do a little summer reading on these industry innovations.
Joining Dissimilar Material Systems

Project: Multimaterial joining
School: Michigan State University
Location: East Lansing, Mich.
Principal Investigator: Mahmood Haq

Mahmood Haq’s research on multimaterial joining made headway in 2012 when the assistant professor in civil and structural engineering at Michigan State University (MSU) received a three-year grant from the U.S. Army to study joining composites to steel and aluminum for military ground vehicles. “That was the turning point,” says Haq, a faculty member in MSU’s Composite Vehicle Research Center (CVRC). “We learned a lot of valuable lessons about the challenges of taking this work to an assembly line. Joints that take four to six hours to cure in an oven are not feasible for automotive applications, where cycle times are measured in minutes and seconds.”

Haq says the importance of researching automotive structural joining is simple. “Joints are the weakest link,” he says. “If you can understand the joints well, then you can design the structure well.” That is a relatively simpler task when similar materials are joined. But the focus on lightweighting cars to increase fuel efficiency and reduce greenhouse effects has led to strategic replacement of some metal components with composite ones.

“When you replace a few components with composites and the rest are metal, you have a new problem,” says Haq. “Joining similar substrates – such as composites to composites and metal to metal – is relatively easy. But how do I join composites to metal?” Traditional methods don’t work. For example, drilling a hole in composites sacrifices up to 60 percent of the load carrying capacity, says Haq. “The minute you drill a hole, the fibers become discontinuous, you create stress concentrations around the hole and you cause delamination, all of which act as failure initiation points, thereby weakening the resulting joints.”

Adhesive bonding also presents challenges. “That is a one-time cure,” says Haq. “Once the adhesive cures, the joint can’t easily be undone. To repair a part, you have to change the entire component rather than fix a small part of it.”

These limitations led Haq’s team at the CVRC to create several novel joining technologies, including advanced adhesives with special properties that allow them to be taken apart, repaired and healed. Funding by the U.S. Department of Energy and the American Chemistry Council has allowed the group to research the use of thermoplastic adhesives embedded with electrically conductive nanoparticles for multimaterial joining.

Unlike thermosets, thermoplastic adhesives can be heated and separated at will for repair or reassembly. Haq added conductive metallic nanoparticles to the thermoplastics, then used electromagnetic radiations to activate only the glue – not the substrate. “We can very rapidly just heat the glue and separate the two joints,” says Haq. “In our lab, we have shown that up to a 2 x 2-foot panel can be separated in less than one minute.”

However, there are limitations based on the electromagnetic radiation used for activation of the adhesives. For instance, microwave activation is currently limited by the size of the microwave. Although equipment manufacturers are developing applicators that can go on the end of a robotic arm, Haq has moved forward with other activation techniques research to bypass the problem. For instance, metallic nanoparticles derived from iron ores can be activated using induction systems to heat up the glue.

“We’ve been able to join large areas, as well as dissemble, reassemble and repair large areas of joints,” says Haq. “Furthermore, if we control the amount of electromagnetic radiation – specifically the induction system – we can actually heal the joint.”

The researchers ran samples through thousands of fatigue cycles, simulating the damage done by repeatedly driving on roads with potholes. They healed the joint, then pulled it apart to examine it. “The healed joint exhibited no fatigue,” says Haq.
“In other words, we can rearrange polymer chains, heat the adhesive as if it’s brand new, close the cracks and refurbish or refresh the joints as though nothing has happened.”

Haq’s team has tested several thermoplastic materials, including nylon 6, polycarbonate and acrylonitrile-butadiene-styrene (ABS). They are now working with high-impact polystyrene (HIPS).

The group also is in discussion with a couple of OEMs and Tier-1 suppliers to demonstrate feasibility on a composite part in the next few months. In addition, the researchers are developing a coil induction system that can be mounted on a robotic arm for use on an assembly line. Finally, the team is doing a lot of modeling and nondestructive evaluation to better understand the joints.

“We strongly believe that integration of models and nondestructive evaluation, combined with multimaterial joints, will take automotive composites to the next level,” says Haq.

**Morphing Wings Take Flight**

*Project:* Cellular Composite Morphing Aircraft Wings  
*School:* Massachusetts Institute of Technology (MIT)  
*Location:* Cambridge, Mass.  
*Principal Investigator:* Neil Gershenfeld

Researchers at the Massachusetts Institute of Technology (MIT) and NASA are experimenting with bendable, morphing aircraft wings that are built like a giant Lego® set – one cellular composite building block at a time.

Building lattice wing structures with tiny modular pieces – or “digital composites” – provides many advantages, including significant weight savings, increased flight control and the ability to utilize novel manufacturing techniques, according to Benjamin Jenett, graduate researcher at MIT’s Center for Bits and Atoms (CBA) and a NASA fellow. NASA’s Ames Research Center leads the project and partners with CBA, headed by Director Neil Gershenfeld. One of NASA’s investigators, Kenny Cheung, began the body of research at CBA as a graduate student.

The first version of the morphing wing, the Mission Adaptive Digital Composite Aero Structure Technologies (MADCAT) V0, was built from 100 interlocking, diamond-shaped pieces of six different designs, each less than three square inches. The parts were cut using a waterjet machine from 2 x 4-foot quasi-isotropic, CFRP sheets. A pneumatic drill mounted to the waterjet head pre-pierced the sheets to prevent delamination.

The parts were then hand-assembled into the lattice wing structure, with each interlocking piece affixed to another using a snap fit mechanical joint system and zip ties. Discrete pieces of 0.13-millimeter thick Kapton® polyimide film were laser cut into strips and used to create a non-structural skin with overlapping pieces resembling fish scales that slide over each other as the wing morphs. A full-span wing was tested in both MIT’s 8-foot Wright Brothers wind tunnel and NASA Langley Research Center’s 12-foot wind tunnel. Then a small, radio-controlled motor and propeller were added to complete the aircraft, which was tested at NASA’s Crow’s Landing flight facility.

The test wing structure provides an incredible stiffness-to-weight ratio, says Jenett. He notes that although cellular solids are a well-researched area of materials science and that there is “nothing magical about the geometry itself,” the ultra-lightweight, ultra-performance of these cellular solids had previously only been demonstrated in extremely small, millimeter-sized applications like aerogel materials. By using discrete lattice assembly, the approach can be scaled up to the size of an airplane.

The cellular wing structure was designed so that the core of the wing has a different geometry with more struts and lattice elements per unit volume than other areas, making it denser and stiffer than more sparse areas. This varied geometry, which creates some stiff areas and some flexible areas, enables the wing to be twisted (or deformed) as one piece with just a small motor on each wing tip, while staying very stiff in span-wise bending. This ability to morph the entire wing eliminates the need for multiple wing flaps and their heavy actuating systems, further reducing weight and decreasing drag. It is also reminiscent of the first airplanes with wood and canvas wings that were manipulated as one unit using cables and levers.

“Our system opens up a whole new avenue of returning to the origins of aircraft, thinking less about mass sensitive actuation systems and thinking of an aircraft as one giant, deformable structure,” says Jenett.

The next version, MADCAT V1, which is scheduled for wind tunnel testing in July, will increase the wingspan from four to 14 feet – almost the size of a small passenger aircraft. It is constructed
from over 2,000 injection-molded GFRP parts for fast production – up to 10,000 parts a week. Jenett says that while GFRP is sufficient for current testing, researchers will return to CFRP at a later point for higher performance. In another nod to speed, the V1’s parts are being attached using nuts and bolts, which allows researchers to build structure volume quickly.

Ultimately, Jenett says that researchers at the CBA and NASA would like to design integral, bi-stable connectors that can be injection molded on the part or added as a secondary step before assembly. This would eliminate the need for the millions of fasteners found in modern aircraft like the Boeing 737. “So, you wouldn’t have any fastener hardware,” Jenett explains, “You would just click the pieces together like Lego bricks, but they would be structural.”

Later, MADCAT V1’s parts may be assembled by small, simple robots. Jenett and the NASA team are currently experimenting with several prototypes of 12-inch or smaller robots that can crawl along and through the structure, return for parts and continue to build the lattice structure.

Ultimately, the combination of small, modular composite parts and discrete assembly using lattice-building robots has the potential to revolutionize aircraft manufacturing.

**Turning Coal into Carbon Fiber**

**Project:** Coal-derived carbon fiber  
**School:** University of Utah  
**Location:** Salt Lake City  
**Principal Investigator:** Eric G. Eddings

Researchers at the University of Utah’s Industrial Combustion and Gasification Research Facility hope to breathe new life into Utah’s rural coal-based communities by developing cost-effective ways to produce carbon fiber from coal.

American coal is primarily used to generate electric power. In contrast, petroleum has been developed into a range of products that include commodity chemicals, plastics, polyesters – and PAN-based carbon fiber. In fact, more than 90 percent of the world’s carbon fiber is derived from PAN. “Coal, in like manner, could be considered raw material for a number of different products,” says Eric G. Eddings, a professor and associate dean for research in the College of Engineering at the University of Utah. “It’s just that we haven’t historically done that.”

To help develop carbon fiber from coal, Eddings and his team have embarked on a three-year, $1.6 million research project that includes a $790,000 POWER grant from the U.S. Economic Development Agency (EDA) and collaboration with the University of Kentucky and the Utah Advanced Materials Manufacturing Initiative (UAMMI).

Researchers will collect samples from Utah coal mines and create tar samples that can be further processed to form “pitch.” This pitch will be spun into carbon fiber at the University of Kentucky Center for Applied Energy Research, which has one of the country’s few production lines for smaller-scale spinning of experimental carbon fibers, according to Eddings. The team hopes to identify cost-reducing approaches to carbon fiber production. These may include identifying coals or processes with higher pitch yields, reducing processing time and developing processes to create high value co-products that can be sold to offset costs. Or, as Eddings sums it up, “Anything to save money.”

For now, the Utah team is processing the coal using pyrolysis. The coal is first ground into a fine dust and then heated with a simple laboratory reactor as an auger pushes it through a furnace. This decomposes the coal’s large hydrocarbon molecules into smaller gaseous molecules, or vapors. The vapors are then cooled, and the heavier molecules used in the production of pitch condense first, as tar. This tar is then distilled to separate the pitch, which can then be upgraded to mesophase pitch via heat treatment under inert conditions. In contrast to isotropic pitch, Eddings says, “Mesophase pitch has liquid crystals in it that help create highly graphitized and ordered carbon fiber that has much, much better properties.”

The team will send the first batch of pitch, derived from coal from Utah’s SUFCO mine, to the University of Kentucky in July. Pitch from other regional coals will be derived and tested continually over the next few years to determine which may have a greater propensity for producing a large pitch fraction or a very high-quality pitch.

As pitch production continues, researchers will also test various approaches to create as many co-products as possible to make carbon fiber from coal economically attractive. The vapors that remain after the pitch has been collected can also be condensed into a range of gaseous and liquid hydrocarbon products that include hydrogen, methane, ethane and other light hydrocarbon gases, liquid paraffins, akyl-benzenes and phenols.

One issue faced by the team concerns lingering inorganic content. Coal has 10 to 40 percent inorganic content that is left behind as residual ash, and small amounts could end up in the tar after the hydrocarbons have been processed. This creates challenges, especially compared to processing carbon fiber from petroleum, which has only trace amounts of inorganics, Eddings notes, that are “relatively small and generally much easier to deal with than the rock-like material, aluminosilicates, iron pyrites.”
and those kinds of things that you find in coal. “

Nonetheless, Eddings sees these inorganic materials and solid carbon residues as another source of co-products that can offset carbon fiber production costs. Residual carbon “char” or “coke” is already typically sold as metallurgical coke for steel processing, while residual ash could also be used as a source for rare earth materials.

Eddings notes that although companies such as Mitsubishi are producing carbon composite products derived from coal, it is a tiny percentage of the market. Ultimately, he hopes that this research will contribute to innovations needed to sell coal-pitch derived carbon fiber at $5 per pound – the price widely seen as the key to breaking into the automotive industry.

“That would be the dream,” says Eddings. “That would have a significant positive impact on many of these coal communities who will have found a new, high-tech use for this great and very large U.S. resource.”

**Suiting Up for the Red Planet**

*Project:* Z-2 space suit  
*School:* University of Delaware  
*Location:* Newark, Del.  
*Principal Investigator:* Jack Gillespie

When NASA prepared to travel to the moon in the 1960s, it required space suits for astronauts that could endure 83 percent less gravity than earth and no significant atmosphere. ILC Dover Inc. supplied space suits for NASA’s Apollo program. More than 50 years later, the company continues to provide space suits – with much more stringent requirements. They must withstand conditions on Mars.

As the prime contractor on NASA’s suit program, ILC partnered with the University of Delaware’s Center for Composite Materials to design and manufacture space suits that can hold up to the red planet’s harsh environment: average temperatures of minus 81 F, a gravity just 38 percent that of earth’s and an atmosphere that’s mostly carbon dioxide.

“The genesis of our partnership with ILC on this project was matching their expertise in soft composite materials with ours in hard-shell composites to do something that hadn’t been done before and meet the requirements for the Mars space suit,” says Jack Gillespie, an engineering professor at the University of Delaware and director of its Center for Composite Materials (CCM).

NASA had very specific requirements for fit and function, one of which related to the low gravity on Mars. During planetary exploration, astronauts could fall onto hard objects. “The composite components subjected to that impact loading could not leak and had to retain vacuum integrity,” says Gillespie. To help protect the astronauts, NASA opted for lightweight, hard-shell sections on the torso of the new space suit, called the Z-2. Composites are utilized in three areas: the hard upper torso (HUT) covering the chest, the brief around the waist and upper legs, and the entry hatch, which is a backpack mounted to the back of the HUT.

“The HUT had to have articulating components so the astronauts could move around, and the components had to be integrated into vacuum-tight joints when you assemble the space suit’s soft components with the hard ones,” says Gillespie. “And of course, we had to find a way for the astronaut to get in and out of the suit as well.”

The HUT, brief and hatch, which were designed at the CCM’s Applications & Technology Transfer Lab (ATTL), utilize IM10 carbon fiber as the primary reinforcement. “We did a lot of internal work looking at representative impact loading of candidate laminates to test and prove out the performance,” says Gillespie. “That led to hybridization of the carbon fiber with some strategically-placed glass. Ultimately, that turned out to offer the minimum weight solution to survive the impact load.” The high-modulus, woven fabric carbon fiber is used in tandem with S-glass and an epoxy resin system.

“These structures were highly-tailored in terms of ply orientation and thickness and ply drops for minimum weight,” says Gillespie. “The HUT and brief had complex geometries, so we developed hundreds of custom patterns for mapping the plies onto the geometries and achieving the optimum orientation without inducing wrinkles and other flaws.” Each pattern was made, cut automatically, placed using a laser projection system, then debulked for optimal consolidation of the structures.

Throughout the process, the ATTL conducted numerous
tests on materials, sub-elements and test panels, ranging from materials and chemical characterization tests to impact simulations. The HUT, brief and hatch were manufactured using “very traditional aerospace-level processing,” says Gillespie. The hard components were then delivered to ILC, which created the soft armor and assembled the space suit. The Z-2 prototype was delivered to NASA in March 2016.

Gillespie says NASA has begun using the Z-2 in astronaut training programs. It also put out solicitations for Small Business Innovation Research (SBIR) projects. Three of CCM’s spin-off companies won bids: Composites Automation, STF Technologies and Maher & Associates.

Gillespie hopes that the Center for Composite Materials will be involved in future work on the Z-series of space suits for Mars, working to improve the toughness, reduce weight and enhance producibility. “Given the finite length of time we had to work on the suit, we hybridized the composite components and met NASA’s requirements,” he says. “But there is room for improvement. With more materials development and studies, there are big opportunities to develop better materials and save even more weight.”

Riding Out the Storm

Project: Weather-predicting UAVs
School: Oklahoma State University
Location: Stillwater, Okla.
Principal Investigator: Jamey Jacob

Last year, more than 970 tornadoes ripped through the United States, according to the National Oceanic and Atmospheric Administration (NOAA). Given that the average lead-time for tornado warnings is only 13 minutes, it’s no surprise that researchers are working on ways to extend the time between advance warnings and tornado strikes. Students at the Oklahoma State University Unmanned Systems Research Institute (USRI) are pinning their hopes on sensor-laden unmanned aerial vehicles (UAV) made from composites.

Alyssa Avery, a graduate student in the aerospace engineering program at Oklahoma State University, began designing a weather-sensing UAV three years ago. Her system, called the Mesocyclone Analysis Research & Investigation Aircraft (MARIA), can be loaded with sensors to measure temperature, pressure, wind velocity and other factors. It’s one of several UAVs developed for weather applications under the guidance of Jamey Jacob, professor of aerospace engineering at Oklahoma State University and director of the USRI. The project is part of an effort funded by the National Science Foundation that also involves the University of Nebraska, Oklahoma University and the University of Kentucky.

Avery had always dreamed of building an aircraft, so when other students in the USRI wanted to become more involved in meteorological sampling the timing was right. “I’ve lived in Oklahoma all my life, and tornadoes have always been a part of life,” says Avery. “This was a great opportunity to build an aircraft with a purpose.”

Located in the heart of Tornado Alley in the sweeping plains of the United States, Oklahoma averaged 60 tornadoes a year between 2005 and 2014, according to the NOAA. The ultimate goal of the UAVs built by Jacob’s team is to improve understanding of weather phenomenon, particularly severe weather such as thunderstorms and tornados, by providing measurements of thermodynamic parameters and using those to enhance meteorological forecasting models and improve forecast accuracy and warning times.

To collect data, the UAV needs to be both light weight
and sturdy, so composites are an ideal material. “Without composites, the aircraft would not be able to withstand the severe environment of a thunderstorm,” says Jacob.

MARIA is made primarily from epoxy resin reinforced with 3-ounce woven E-glass and 3.5-ounce woven carbon fiber or other high-performance fibers in spots requiring extra strength. The wing skin has four layers – fiberglass, 2-ounce aramid fibers, ¼-inch vinyl foam and another layer of fiberglass. The fuselage skin has the same construction, but uses carbon fiber in place of the aramid. It also features an extra layer in high stress areas, such as the small diameter areas of the empennage. In addition, the UAV has 4.7-ounce layers of carbon fiber in the C-channel as the main support for the wing.

Fabricated via vacuum bagging, MARIA weighs 12 pounds unloaded and 35 pounds with sensors – a mix of off-the-shelf and custom ones. While the UAV has done test flights, it hasn’t yet flown during a tornado. It currently takes several hours to prepare for flight, which is not conducive to chasing fast-developing tornados. However, MARIA and other UAVs fabricated by Jacob’s team have flown successfully in storms.

The work done by the aerospace engineers at Oklahoma State University has garnered the attention of meteorologists at the National Weather Service, National Severe Storms Laboratory and other institutions, who hope to use the data collected to learn more about weather and track weather patterns. Ideally, more insight will lead to better tornado models and more accurate tornado warnings. Avery also has fabricated a second composite UAV for icing studies which will begin next spring.

Jacob says the only other tornado-sensing UAV system that he’s aware of is the Tempest, a modified powered glider designed by a company called USAUSA for the University of Colorado. Most systems used to collect data from inside a storm rely on dropsondes – instruments dropped by parachutes from aircraft to obtain temperature, pressure and moisture measurements.

“They require an aircraft to fly above or into a storm, and once the dropsondes are deployed they can’t be controlled and aren’t usually recovered,” says Jacob. “We hope our UAVs would replace that process with a more controlled system to provide more data.”

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Back in the 1970s, when the CEO of a major aircraft manufacturer proudly announced that his company had produced a virtual model of an aircraft fuselage, he was referring only to the geometry of the fuselage. The model didn’t include the aerodynamics for calculating the air flow patterns over the wings and fuselage because the technology simply wasn’t sophisticated enough. Simulations at that time had only about 5,000 degrees of freedom – or independent parameters for modeling.

Contrast that to the capabilities of current models. “In today’s world, we literally model with millions of degrees of freedom, so that we can make the virtual twin look almost exactly like the real thing to the extent that you put all the physics in the simulation and modeling,” says Byron Pipes, an engineering professor at Purdue University and the director of the design, modeling and simulation technology area at IACMI—The Composites Institute.

Those advances in aircraft modeling are reflected in the composites industry, where simulation programs for the design of composite materials and products have grown more complex, more comprehensive and more detailed. But there are still gaps in composites models that both industry and research organizations are working to overcome.

Above: Professor Wenbin Yu (standing), director of the Composites Virtual Factory HUB at Purdue University, studies a composite simulation with Bo Peng (left) and Ernesto Camarena, graduate research assistants.

Simulations Speed Development

Detailed models shorten time from design to production.

By Mary Lou Jay
Evaluating Performance

Chintan Ved, senior engineer for materials development at Ford Motor Company, employs simulations to determine which parts in vehicles’ transmission and drive lines could be manufactured from composites to reduce weight. “We use all of the analytical tools which we have within our system and in the industry in general to convince us that [the composite] meets the performance criteria and at the same time extracts the benefits of new materials that have been developed by the industry,” says Ved.

Modeling composite parts helps Ford engineers understand the tradeoffs involved when they’re using the material in each application, part or duty cycle, he says.

Ford has adapted its proprietary simulation software, which it has used for years in working with metals, to model composites. But the automaker also works with resin manufacturers, who have developed their own mold flow analyses. “The resin manufacturers do a good job with that, so we combine that and feed it into our regular CAD and CAE models to make sure that between the brains at both houses we don’t miss anything,” says Ved.

He would, however, like to see models that could predict mold flows even more accurately, which could eliminate some prototyping stages. “If we could avoid that, it would help us get our products to the market faster,” he says.

Another thing that today’s modeling programs can’t do is predict how the composite materials will perform over time, such as after being installed in a vehicle for 150,000 or 200,000 miles. “We are talking about material compatibility, about heat and how the molecules are changing and how the performance and the crystals of the resin are changing; it’s very complex,” says Ved. For example, models that could predict that the material would not degrade any more than a certain tensile strength loss or elongation loss over time would save the automotive industry time and money.

Minimizing Testing

When the aerospace industry was developing the Boeing 787 and the Airbus A350 a dozen years ago, the Federal Aviation Administration (FAA) was concerned that the composite materials being proposed for the new planes would not offer the safety of metallic structures. “So they were going to require [the manufacturers] to come back to scale testing of this new science, something that is almost impossible to do with big aircraft,” says Gerado Olivares, senior research scientist and director of computational mechanics and crash dynamics laboratories at Wichita State University’s National Institute for Aviation Research (NIAR).

NIAR has been working with the FAA since that time to develop techniques that will allow aerospace manufacturers to minimize full-scale testing for some applications, including the dynamic seat certification of both composite and metallic aircraft seats. “It has taken time to develop the metrics, and we are now working with the industry to implement all of these methodologies that we have developed,” says Olivares. “We have asked to use simulation to support the certification process, so that instead of having to run a full aircraft, you can just run a small section of the aircraft for the testing to validate the models.”

Using simulation programs, NIAR researchers have also gained a better understanding of the effect of bird strikes on the composite structures on aircraft exteriors. In the past, all of this work on dynamic impact was done by physical testing. But with these physical tests, researchers had trouble determining exactly what had happened during a failure, since they had only high-speed video or measurements from strength gauges to review. “You never know the sequence of the failure or the dynamic loads going through the structure at the time of the impact, because you don’t have any source of measuring that. So one thing that we’ve been able to do now with simulation is really quantify what all those loading conditions are,” says Olivares.

NIAR researchers have recently been working with software company Dassault Systèmes and its 3DExperience® software platform to develop these simulations.

“This is a solution for composites design and manufacturing preparation in simulation,” says Rani Richardson, Dassault’s composites and additive manufacturing industry consultant. “We are able to take our customers from conceptual design to detailed design to virtual testing and then actual specification on the shop floor.”

With the composite workbench on the 3DExperience platform, a composite designer can define what a composite’s ply lay-up will be and then virtually simulate its draping to see how it lays. A designer can also simulate how plies will be staggered, how they are inverted and if there are darts needed, making the manufacturing process easier.
The integration of various modeling tools in the 3DExperience platform allows the data about a composite product to flow seamlessly from one application to another, extending the simulation into the manufacturing environment. "If you want to do a hand lay-up process, we would be able to take the data in the composite workbench and use it in the composite laser application," says Richardson. In addition, because the applications share the data, a change to the design is automatically updated in the laser projection output, maintaining the data integrity throughout the process.

"The idea is to do this all virtually before you actually get to the shop, because you want to reduce that variability and the number of iterations on the shop floor," says Richardson.

While NIAR researchers validate certain aspects of their simulations with coupon and component-level tests, they hope to eliminate some of that testing to speed product development.

"We want to conduct full-scale evaluations with the first prototypes rather than having to build multiple prototypes," says Olivares. For instance, NIAR recently assembled an unmanned aircraft system (UAS). It conducted extensive modeling on the UAS and planned to flight test it in early summer to make sure that everything that was predicted on the computer applies in the real world. "If we can accomplish that it will be great, because then we can minimize the number of physical prototypes that we have to build in the development process," says Olivares.

Looking at the Gaps

One piece currently lacking in the 3DExperience platform is a tool that enables composite designers to experiment with different combinations of matrices and fibers to test their properties. However, Dassault's Biovia software does provide those capabilities on a separate platform. "With Biovia, we learn more about the different effects of resins and materials during different manufacturing processes," says Richardson. "You can see what's happening with the materials as they go through the curing process, and you can also see what's happening in their afterlife."

Olivares says that such tools are needed because NIAR currently must use very generic models that don’t allow it to capture the details of various fibers and matrices. "Right now, we compensate for that lack of fidelity of models with a lot of testing at the coupon and the component levels, so that we can fine tune the models using those specific tests. But it will be very helpful in the future to have better models that are able to capture these failure mechanisms," says Olivares. Researchers are currently working on micro, meso and multi-scale path analyses for composite materials, which could result in more predictable models that will not depend as heavily upon the coupon and component testing.

Modeling all the complex mechanics of failure in the matrices or fibers would take a very long time to compute, Olivares says. But he remains hopeful that such models will eventually reduce the need for some testing.

"If this approach takes off, we will be able to generate mechanical properties as part of simulation models and that will make things move toward the virtual wall that will enable the fast design of materials in initial life," he says.

Accounting for Unique Properties

Engineers who want to design with composite materials often wish for a database of composite properties similar to the ones that exist for various metal materials. But Pipes says that’s not realistic since each combination of a fiber and continuous base creates a new material. Change the percentages of materials in a composite, change the shape of the fibers or change the way that they are manufactured and you get a material with different properties.

"That’s a problem, because now the guy that wants to use it doesn’t know what its properties are," explains Pipes. Two-phase composites – a matrix and a fiber – are complicated enough to define; when you add in another phase – the interphase, or interface between the matrix and fiber – there are millions of combinations (and variations in properties) that could result.

Simulations, rather than databases, are the answer, says Pipes. "If I can simulate the properties, if I can predict them from the composition and the makeup of the composition and the meso structure of the composition, then I don't have to measure them. I can predict millions of combinations, then pick what I want and do a few tests to substantiate the properties of that combination. But that’s not where the world is today," Pipes adds.

Although composite modeling tools have existed since the 1950s, it's only recently that they've been able to capture the complexity of a composite.

What's changed is computing power. "You have more computing power in your phone today then we had at General Dynamics when we were trying to build airplanes in the 1970s,"
Composites Manufacturing says Pipes. “Now that we have this power at our fingertips, we finally have the simulation tools that we need to model every possible material combination or meso structure.”

But looking at the combination of materials is just the start. “Since the properties of the materials change by the way you make the material, you have to model and simulate the manufacturing process as well,” he says. In injection molding, for example, the way the material flows into the mold changes the fibers’ orientation, which means that one part of the composite will have different properties than another section that’s just two inches away. “So within this same manufactured part you have an array of materials; you do not have a single set of properties,” Pipes says.

The properties of the material also change depending on the way the material fits in the mold. Take a flat sheet of woven fabric and drape it over a complex shape like a car part, and the angle between the fibers moves from being perpendicular to one another to some different angle to one another. So every point in the composite part has a different set of orientations and thus different mechanical properties.

To determine all of a composite part’s properties, then, requires modeling not only the materials that went into its manufacture, but also the physics of the manufacturing process.

Bringing It All Together

When modeling composites, Purdue researchers work with 10 or 12 different computer codes (which are the base of the computer models) from several different companies. Purdue researchers are knitting all of those existing codes together to provide a single program that includes all the information in those various codes. In cases where there’s a gap, Pipes and his team are working on developing interfaces between existing commercial codes to fill them.

The researchers are already teaching OEMs and other companies how to assemble the codes and build these connecting pieces. “When they’re done, they’ll be able to model from the beginning of the manufacturing process all the way through the performance of the product,” says Pipes.

But most small to medium-sized companies don’t have the computing power to work with such complex models. So Purdue has put this connected package of codes online in the Composites Virtual Factory HUB, which allows users to log in and run composite simulations online. This online modeling program can be used only by IACMI members for IACMI projects, but Pipes believes that a commercial version will be available in about three years.

Pipes notes that the ability to predict composites’ behavior from complex models is especially important for 3-D printing applications. Using simulations, Purdue researchers were able to predict the performance characteristics of 3-D printed tools. They could look at the way that the carbon fibers in the tool would orient with the direction of deposition and at how the tool would change shape as it cools.

“When you can predict that, you can design the tool to be the right shape after it cools, which is what you want the part to look like,” says Pipes. The combination of modeling and additive printing will change composites manufacturing, because together they provide the ability to make tooling prototypes quickly — often overnight.

Modeling has the potential to unlock a whole new range of opportunities, says Olivares. “If you want to innovate, it’s very hard to do through physical testing because of the limitations of budget and time,” he says. “If we really want to introduce new composites, new materials into industry, we need to find a way to be able to properly simulate them with minimal costs from a coupon and a component level testing point of view.”

Mary Lou Jay is a freelance writer based in Timonium, Md. Email comments to mljay@comcast.net.
The life of a certified public accountant can be exhausting. It’s an arduous job with long work days and painstaking number crunching. But according to Kevin Barnett, ACMA’s incoming Chairman of the Board of Directors, that early-career desk work is nothing compared to his upbringing. As a boy growing up in rural southern Ohio, Barnett spent most of his days helping maintain the family farm. The self-described “country boy” figured he would never leave his small town, but after graduating from Ohio University and marrying his high school sweetheart, he moved to Columbus, Ohio, and began his career with Deloitte & Touche LLP. By then, his tolerance for long hours was ahead of the curve. “I remember thinking, ‘Wow, this is pretty good.’ I used to work longer hours and got paid with three meals and a roof over my head,” Barnett recalls. While farming taught him the value of hard work, he admits it was often physically draining and unpleasant. Back then, the outdoors just represented hard labor, but after living in Columbus for more than 30 years, he now sees being outside as an opportunity to appreciate nature.

It is perhaps that attuned awareness of his environment that has made him the detail-oriented worker and open-minded leader that he is today.

Leadership Qualities

Barnett got his start in composites in 1997 when he left his position as vice president, treasurer and corporate controller at Medex Inc. – a manufacturer and marketer of injection molded products for the medical market – for Core Molding Technologies. Core is a manufacturer of sheet molding compound (SMC) and a molder of fiberglass-reinforced plastics (FRP). At the time, Barnett didn’t know much about composites but was intrigued by the industry and specifically the opportunity to join the newly formed Core Molding Technologies.

“The more I researched composites, the more I was intrigued by the opportunity to enter a growing industry,” says Barnett. “I also felt that Core was well positioned to capitalize on that growth.” According to Forbes, he was right, as Core was ranked No. 126 on Forbes’ best small companies list in 2006. In 2014, seven years after Barnett took over as CEO, Core shot up the list to No. 37. In the 20 years Barnett has worked at Core, the company has grown from one location, one process and a couple of customers to five manufacturing locations, a wide range of thermoset and thermoplastic composite manufacturing processes and multiple blue-chip OEM customers in the heavy truck, automotive, marine, construction and telecommunication industries.

According to Terry O’Donovan, Core’s vice president of marketing and sales who has known and worked with Kevin for more than eight years, a large part of what has made Barnett successful is that he doesn’t fit the stereotype of a CEO. He’s not the type to comment on everything during a meeting, but when he does, his comments are strong, thoughtful and based on a comprehensive understanding of the issue at hand and everyone
That benefit members and the composites industry at large. That
does not mean, however, that money will be the sole focus of
Barnett’s tenure. While finding ways to generate revenue is
important, Barnett is also focused on making sure businesses get
the most out of their ACMA membership.

“It’s really not just about writing the check and paying dues,
it’s how you get involved in the association,” Barnett says. That
can include participation on committees to help set the direction
of ACMA and what the association is doing to advance the
industry, or investing in your composite skills by becoming a
Certified Composites Technician, attending CAMX or using
the ACMA Buyers’ Guide. Access to all of these programs, as
well as what ACMA does to represent composites businesses in
Washington through regulatory and legislative advocacy, were
some of the driving forces behind Core becoming a member.

But beyond access to ACMA programs, Barnett says
composites businesses should join ACMA for a more intangible
reason that perhaps parallels his appreciation for nature. For
many people like Barnett, there’s something about being in
nature that helps broaden your view of the world beyond your
own life. Similarly, being part of ACMA has exposed Barnett
to different material systems and processes, as well as different
markets, and to many great people he may not have otherwise
known. And as a result, his understanding of the industry and the
opportunities for composite manufacturers has grown.

ACMA’s members have a huge well of collective knowledge,
experience and process capabilities. Sharing that knowledge
with OEMs and other potential composite users and specifiers,
Barnett says, is one of the biggest challenges facing the industry
today. While industry issues of lowering costs and cycle times are
important, Barnett says the greater overarching issue is awareness
of composites. Oftentimes, Barnett says, Core will find itself in
a position where it has identified a potential customer with a
specific need, and the critical decision makers at that company
never even thought of FRP as an option.

“They don’t even know they have a need for our product,”
Barnett says. “And the level of understanding and awareness is
certainly not to the level it is with some other technologies and
some other materials, and I think that’s one of the things we in
the industry need to collectively work to change.” Under Barnett’s
leadership for the coming years, ACMA will be rolling out a
targeted marketing and public relations campaign that will work to
raise this awareness among potential users of composite materials.

Barnett sees a lot of opportunities to build on ACMA’s
strong market development efforts and views infrastructure and
transportation as prime growth areas in the composites industry.
With all the opportunities Barnett sees for composites and his
belief that ACMA plays a part in helping the industry work
together and grow, it is no wonder why his focus is on increasing
revenue and member engagement with the association.

“What excites me is to see how folks in our industry go about
having the perseverance, dedication, drive and patience to help
solve those problems and pursue those opportunities that are out
there,” Barnett says.

Evan Milberg is communications coordinator for ACMA. Email
comments to emilberg@acmanet.org.
Composites Manufacturing

Prop 65: What You Need to Know

By Evan Milberg

One of the most common chemicals used in composites manufacturing is styrene. Most of the styrene used to manufacture composite products is consumed in the chemical reaction that creates FRP, but a small amount of residual styrene can remain in the final products.

This issue has led to a challenge that many composites manufacturers face today: compliance with California’s Prop 65 regulation. Also known as The Safe Drinking Water and Toxic Enforcement Act of 1986, Prop 65 was passed with the goal of protecting drinking water sources from toxic substances that may cause cancer and birth defects, as well as reducing or eliminating exposure to them.

Even after 30 years, Prop 65 remains politically controversial because many believe it puts the burden of proof on businesses instead of the government to make a key scientific determination about safety levels for specific toxic chemicals. According to the California EPA (CalEPA), Prop 65 has “increased public awareness about the adverse effects of exposures to listed chemicals” and “provided an incentive for manufacturers to remove listed chemicals from their products.” However, although the regulation may have allowed Californians to make better-informed purchasing decisions, it has come at a cost for companies doing business in the state.

Prop 65 regulates toxic substances by placing any chemical that the state decides has a 1-in-100,000 chance of causing cancer or birth defects over a 70-year period on a special list. Last year, CalEPA’s Office of Environmental Health Hazard Assessment (OEHHA) ruled to add styrene to the list. That means that if a business manufactures, distributes or imports products containing styrene that are sold in California it may have to provide toxicity warnings on those products. However, although the regulation may have allowed Californians to make better-informed purchasing decisions, it has come at a cost for companies doing business in the state.

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However, there are two exemptions to the rule. Warnings are not required for companies with fewer than 10 employees. Additionally, if a company can show that average daily lifetime exposures associated with use of its product are below what is known as the “No Significant Risk Level” (NSRL) for styrene, which is 27 micrograms per day of exposure, warning labels are not necessary. But because of the way that Prop 65 is enforced, manufacturers that don’t provide warnings can still be the target of expensive litigation even if they believe the styrene exposure associated with their products is below the NSRL. “Failure to warn” law suits as a result of Prop 65 can be expensive, even when resolved in the companies’ favor.

According to ACMA’s research, most composite products are theoretically exempt from the warning requirements because the styrene exposures associated with use of the products may be below the NSRL. However, the association believes that it is important for all composites manufacturers to mitigate any potential risk by taking steps now to develop customized risk management strategies that take potential enforcement and market losses into account. Every company must review the regulation and their own activities and make a decision based on their specific situation. Additionally, ACMA suggests that companies may also want to seek legal counsel to help them make the best decision.

In January, ACMA published Understanding Prop 65: For Composites Manufacturers – a 10-page document that provides critical background on Prop 65, information on compliance and enforcement, best practices to manage risk and answers to frequently asked questions. To supplement the document, ACMA held a webinar outlining the basics of Prop 65. The document and webinar are now available at no charge to ACMA members online at www.acmanet.org/advocacy/regulatory-tools.

Additionally, ACMA members can receive a technical report that describes the results of a study measuring the amounts of styrene contained in a range of composite products. It also estimates the amount of exposure product users and consumers could expect from those products. Composites manufacturers that decide not to provide warnings to consumers in California may be able to respond to Prop 65 enforcement action by using measurements of residual styrene as illustrated in the study.

Some composites manufacturers are providing consumers and customers with warnings to avoid the risk of costly litigation. To take advantage of the Prop 65 warning safe harbor that protects against enforcement, warnings need to comply with OEHHA’s Article 6 regulation. The Article 6 requirements change on Sept. 1, 2018. More information about Article 6 is available for ACMA members at www.acmanet.org/regulatory-tools.

Evan Milberg is communications coordinator for ACMA. Email questions on this column to emilberg@acmanet.org. Email specific questions on Prop 65 to John Schweitzer, senior advisor to ACMA’s president, at jschweitzer@acmanet.org.
ACMA Award Winners!

ACMA is excited to announce this year’s winners of its annual membership awards. On September 11, ACMA will host a recognition ceremony and reception for winners during CAMX. Come and join us to celebrate and recognize these influential leaders of the composites industry. For more information and to get your ticket, visit thecamx.org.

Lifetime Achievement
Bob Long
Marine Concepts

Hall of Fame
Rob Haberlein
Engineering Environmental

Outstanding Volunteer
Robert Steffen
Western Carolina University

Innovative Composite and Metal Parts & Tooling

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ACMA Board Meeting

On May 23, ACMA held a board of directors meeting. The board approved the 2017-2018 operating budget, which continues to support the three strategic goals of market development; advocacy; and education and information.

ACMA recently completed a membership and prospect survey. The survey was conducted by a research firm, which presented its findings and recommendations to the board. The results of the survey indicate that ACMA is delivering strong value to its members, and in many areas performs better than other peer associations or ranks as best in class. The board will work with its various committees to understand how the survey results can be used to help expand and improve upon ACMAs membership offerings.

The Composites Growth Initiatives committees continue developing plans for this fiscal year. A meeting this summer will be held with all CGI committee chairs and the CGI Steering group to discuss and align their activities.

In regulatory affairs, the board discussed Prop 65 and the implications to our membership. Many ACMA members have taken advantage of the guidance documents available on this subject. Work also continues with the National Fire Protection Association on potential

NEW CoREZYN® NSF Approved Vinyl Ester Resin

Interplastic has released a new vinyl ester resin, CoREZYN CORVE8300DW, approved for use in potable (drinking) water pipe and tanks!

This new product can be used in desalination piping and equipment, public drinking water systems and storage tanks containing chemicals such as sodium hypochlorite (bleach), acids and bases.

Put CoREZYN NSF approved vinyl ester to work for you today!
revisions to changes to their code which impacts organic peroxide storage.

Additionally, events, communications and education have continued to grow, with increases in CCT enrollments over the past few months and strong CAMX exhibit sales to date. Readership of Composites Manufacturing magazine online also continues to increase.

ACMA thanks the following individuals whose board term ended on June 30, 2017: John Gaither, Reichhold; Carl LaFrance, Molded FiberGlass; Kim Howard, Owens Corning; Jeff Craney, Crane Composites; Sandy Woodlief, Enduro Composites; and Rob Klawonn, Toho Tenax America, Inc. For more information and to learn how you can get more involved with ACMA, contact Tom Dobbins at tdobbins@acmanet.org.

New ACMA Members

Environmental Composites, Inc.
Tavares, Fla.

GAZ Consulting, LLC
Verona, Wash.

Global Fiberglass Solutions
Bothell, Wash.

Kerrico Corporation
Selinsgrove, Pa.

SGL Carbon Fibers, LLC
Evanston, Wyo.

Spartanburg Community College
Spartanburg, S.C.

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

Advertising Index

Advertiser - Page

AOC Resins .................................. IFC
Composites One ............................. 5
Elliott Company of Indianapolis, Inc. ................. 11
GS Manufacturing ........................ 13
Gurit ............................................ 24
IP Corporation/North American Composites ........ 29
Janicki Industries ........................... 28
LEWCO, Inc. ................................. 20
Master Bond ................................. 28
Thermwood Corporation ................ BC
US Polychemical .......................... 8

BC=Back Cover  IFC=Inside Front Cover
IBC=Inside Back Cover
The preliminary conference program has been announced. With hundreds of topics, technical papers and sessions, this conference offers the most robust conference program in the industry. Tracks include additive manufacturing, advances in materials, business, regulatory and workforce development, recycling and sustainability, manufacturing and processing technologies, market applications and design and testing. To take advantage of the expert speakers and content, choose a full conference or premium registration.

In the almost sold-out exhibit hall, CAMX will house over 500 companies and an all-new area called “Innovation Park.” The park features four areas tailored to the learning, networking and inspirational needs of CAMX attendees:

1) New Exhibitor Zone: In this area of Innovation Park, attendees can discover companies and start-ups new to CAMX. Find out what these companies do and how they benefit you and your business.

2) Consultants Corner: In this area, attendees can get trustworthy, constructive answers to important questions from industry consultants. No questions are off limits here.

3) Presentation Theater: This area will include presentations from CAMX and ACE Award winners, as well as Poster Session winner presentations. Exhibitors also will provide presentations on their products and services, and the area will host press conferences.

4) Connection Zone: In the Connection Zone, attendees can have fun, play games and network. Each day, CAMX will hold meet-ups with attendees with similar interests and crowdsource questions.

Attendees, be sure to get your free exhibit hall registration by Aug. 18. For more information, visit thecamx.org.

Introducing Global Composites

A CMA and NetComposites have joined forces to create a new industry conference, Global Composites, taking place Jan. 31-Feb. 1, 2018, at Caesar’s Palace in Las Vegas. Global Composites will explore the industry from a worldwide perspective, looking at high growth geographic regions with a particular focus on the global supply chain. It will also look at emerging technology trends from around the world and highlight global market information.

Abstracts are now being accepted from potential speakers on subjects relating to advancements and use of composite materials worldwide, including:

- Composite material innovations.
- Manufacturing improvement and innovations.
- Global supply chain.
- Composite industry and end-user market analysis and information.

For more information on registration, sponsorship, exhibitions or paper submission, visit globalcompositesconference.com.
CAMX is the one source for connecting and advancing all aspects of the world’s Composites and Advanced Materials communities: R&D, engineering, manufacturing, service providers, and end-users. Regardless of the application — transportation, aerospace, marine, wind energy, software, construction and infrastructure, medical, academics, sports and leisure — CAMX is America’s go-to event for products, solutions, networking, and advanced industry thinking.

At CAMX you will:
- Discover cutting-edge commercial and industrial applications for advancing the use of innovative, new materials.
- Take part in the most extensive conference program for the industry anywhere in the world.
- Identify new products and geographic markets that can increase sales and your organization’s bottom line.
- Explore and cultivate the CAMX network — enhance your career growth opportunities.
- Uncover areas of untapped growth for your organization.
- Gain the confidence needed to take critical next steps in your business development, while preparing to accommodate new customers.
- Get Business Done - Meet with new customers, current clients and your staff onsite.

Experience the Future of the Industry
At CAMX, you’ll find the best of ACMA and SAMPE — game-changing products and applications, research highlighting uncharted uses for composites and advanced materials, ways to improve tried and true technologies, as well as trends and market analysis. CAMX gives you the unique opportunity to engage with all the experts — as well as the next generation of experts — who are shaping the future of composites and advanced materials... all in one place.

Awards & Innovations
Find the newest, most innovative products, applications, and research on display at CAMX.

The CAMX Award recognizes cutting-edge innovations that are shaping the future of composites and advanced materials in the marketplace.

Sponsored by:

Hosted by ACMA, the Awards for Composites Excellence (ACE) offers six total awards recognizing excellence in Design, Manufacturing, and Market Growth. Sponsored by:

The 2017 Poster Session will feature the latest industry research conducted by students, universities, and companies.

Visit www.theCAMX.org and connect with CAMX on social media.
Pre-Conference Tutorials
Arrive a day early and participate in Pre-conference Tutorials! These 3 hour courses are held on Monday, September 11 and fully immerse participants in a specific area of focus. See the full Conference Program and tutorials at www.theCAMX.org.

General Session & Keynote Address
CAMX 2017 will kick off with an exciting General Session and Keynote Address and awards ceremony featuring the industry’s most impressive innovations.

Conference Program
Delivering detailed Technical Papers, Education Sessions hosted by industry thought leaders, the CAMX Conference Program offers timely topics and industry experts – sharing their knowledge of over 100 different topics.

Attendees can expect the latest applications and research from key areas throughout the industry, arranged within the following tracks:

- Additive Manufacturing
- Advances in Materials
- Bonding and Joining
- Business, Regulatory & Workplace Development
- Design, Analysis, & Simulation
- Green & Sustainability
- Manufacturing & Processing Technologies
- Market Applications
- Non-Destructive Evaluation and Testing

Featured Sessions on Cutting Edge Topics:

- Recycling/Sustainability
- Next Generation Manufacturing/Composites 4.0 (Digitalization of Manufacturing Process)
- Success Stories and Cases Studies
- Simulation and Modeling
- Additive Manufacturing
- Hybrids and Bonding

NEW FOR 2017!

xC Start-up Award
The competition is focused on innovation, the value created by the use of composite materials in the innovation, the role of the partners in the development phase, the benefits for the end-users and market potential of the innovation. The three best-ranked teams can win up to a total of $10,000 prize money. Winners will be announced during the CAMX Luncheon.

CAMX Exhibit Hall Attraction – Innovation Park
- New Exhibitors
- Presentation Theatre
- Consultants Corner
- Fireside Discussions

Register Online Today!
www.theCAMX.org