Making Strides in the Automotive Market

3D Printing Is Transforming Toolmaking

A Strategic Look at Mergers & Acquisitions
About the Cover:
The New York City Police Department replaced three-wheel motorbikes with the Smart Fortwo, a two-seater city car from Daimler AG’s Smart Division. The car features a roof module made from honeycomb composites.
Photo Courtesy of Daimler AG

Building on Success................................. 10
Companies are pursuing various process and product innovations to further penetrate the automotive industry, including resin injection molding, hybrid chemistries, recycled carbon fiber and more.
By Mary Lou Jay

The Next Generation of Tooling.......... 15
One of the hottest applications for additive manufacturing is composite tooling. It allows for speedy production, cost savings and rapid innovation. Discover how it works and who is using it.
By Melissa O’Leary

Get the Most from the M&A Process ... 20
Composites companies entertaining the idea of a potential merger or acquisition, from either side of the table, should make sure they’re prepared to maximize the value they get from a deal.
By Megan Headley
Think Boldly and Broadly About the Possibilities of Composites

A few weeks ago at CAMX 2018, I listened in awe to keynote speaker Charles Kuehmann talk about SpaceX’s goal of creating a rocket to travel to and colonize Mars. My first thought was, ‘Wow! That’s interesting, but I’ll never go to Mars and probably won’t create a product that goes there either.’ But as I pondered the message from Kuehmann, who is vice president of materials engineering for both SpaceX and Tesla, I realized the broader theme of his speech was possibilities – creating opportunities to do things that haven’t been thought of before.

Our industry is also focused on thinking about what’s possible and creating opportunities for innovation. More than 550 exhibitors on the CAMX show floor displayed state-of-the-art products, processes and technologies. I was challenged at both the CAMX Live! opening general session and the exhibit hall to think boldly and broadly. What can I make possible using composites?

A couple years ago, Core Molding Technologies developed a co-molded SMC and aluminum product for an automotive OEM. The part came about because the customer needed more heat deflection. While we could’ve formulated a different material, that would’ve been more expensive. So we thought boldly and broadly, combining two materials. Lots of other companies that serve the automotive sector are thinking outside of the box, too, especially to meet demands for lightweighting. This issue’s article on page 10 delves into automotive innovations.

One of the hottest technologies to hit our industry recently is additive manufacturing. For lots of people, 3D printing has a ‘Gee, golly whiz’ effect: The technology has garnered a lot of attention, but what can you really do with it? A couple years ago, engineers at Core Molding Technologies tapped into the possibilities offered by additive manufacturing to create a 3D-printed gauge to measure dimensions of products that must fit very precisely into complex assemblies. Traditionally, the gauge would’ve been a more expensive, highly-machined device. Elsewhere in our industry, lots of companies are using 3D-printed tooling for speedy production, cost savings and rapid innovation. Read about it on page 15.

Our industry thrives on thinking about what’s possible. I challenge each of you to think boldly and broadly. Who knows? Maybe you’ll be sharing those innovations with peers at CAMX 2019 in Anaheim, Calif.

Sincerely,

Kevin Barnett
Core Molding Technologies
ACMA Chairman of the Board
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Given the importance of continuous fiber reinforced polymer matrix composites (PMCs) for the development of light-weight, fuel efficient, tough, durable and corrosion-resistant structures, the National Institute of Standards and Technology (NIST) has maintained a research program focused on solving problems that impede the widespread use of PMCs. A critical factor controlling composite performance is the fiber-matrix (F-M) interphase region. NIST, in partnership with the composites community, is working to develop the following:

- A standardized test that quantifies the fiber-matrix interfacial shear strength (F-M IFSS).
- A fundamental understanding of how the F-M IFSS obtained from the single fiber fragmentation test (SFFT) correlates to the fracture of fibers in a real composite.
- How composite interphase chemistry and morphology differs from that of the bulk resin and fiber.

Acquiring this knowledge will lead to appropriate modifications to composites that will ultimately result in enhanced toughness and durability.

NIST has made significant advancements in each of these areas. Specifically, the SFFT was expanded to include multiple embedded fibers by redesigning a multi-fiber rotation device to prepare new types of multi-fiber fragmentation test (MFFT) specimen. A critical feature is the precise placement of an array of closely spaced fibers between two single fibers. With an inter-fiber spacing \( d_f \) of approximately one fiber diameter, this MFFT specimen enables the study of the impact of fiber-fiber interactions on composite failure. This understanding will lead to appropriate modifications to composites that will ultimately result in enhanced toughness and durability.
improved device was also used to precisely embed three to five well-spaced fibers in a single specimen. Since the test time for a SFFT specimen is six to eight hours, this new specimen can reduce the effective testing time to one to two hours for each fiber and relies on the fact that fibers do not interact when $IFS > d_f$.

To handle the volume of data from these new MFFT specimen and minimize manpower requirements, an automated machine has been built that takes archival images of each fiber or fiber array. Current efforts focus on developing image analysis methods that will obtain the outputs needed to automatically extract the parameters required to predict full-scale composites performance.

Since matrix crack formation during composite use is known to reduce toughness, NIST has also studied the effects of variations in interphase chemistry on matrix crack behavior – in particular those variations that form during the manufacturing process. Sizing typically deposited on fibers can be very complex, therefore it is essential that the interphase deposition process be controlled on a laboratory scale to understand what factors are essential for enhancing composite performance.

NIST has established deposition protocols that simplify the composite interphase and systematically vary the level of adhesion. The information derived from these studies enables the design of a tough interphase. In addition, a suite of novel mechanophores, such as the one shown above, are being developed to report the existence of matrix damage using fluorescence. This information should provide new insight about how matrix cracks are formed.

Successful implementation of any material in a structural application relies on an understanding of its failure behavior. Techniques and protocols being developed at NIST should provide the tools necessary to achieve this understanding for PMCs.

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The 7M Advanced Combatant Craft (7ACC), displayed at CAMX 2018, represents a new approach to small craft construction for the U.S. Navy. The boat is significantly lighter and more resilient than its predecessors, and its innovative design reduces the risk of injury to sailors who navigate it through rough seas. It took years of work, the development of several new technologies and the close cooperation of many companies to create the 7ACC.

The project began in 2009, when Structural Composites won a grant from the Congressionally-funded Small Business Innovation Research Program (SBIR) to work with the Navy on improving its advanced combatant craft. At that time, the boats’ decks were bonded to the hull, creating a stiff structure that transmitted the shock loads from ocean waves to passengers’ bodies. This caused a high number of injuries. To solve the problem, Structural Composites built upon some work it had done for rescue boats in Norway and for an amusement park’s stunt boat.

“We changed the whole framing of the [advanced combatant] boat; it looks like airplane construction,” says Scott Lewit, president of Structural Composites Inc. and Compsys Inc. Instead of using large stringers – the typical supports for a hull – the new advanced combatant craft utilizes a skeleton grid of PRISMA®, a composite preform made of fiberglass knit fabrics and flotation-grade polyurethane foam.

Rather than attaching the deck to the hull, Structural Composites used large PRISMA cross sections to form the deck framing. The deck is then connected to the boat’s gunnel – the top edge of the sides – so it floats suspended over the hull. When the small 7ACC craft takes a hit from a wave, the shock waves are first absorbed by the boat’s more flexible hull, then passed through the sides to its suspended deck. That greatly reduces the impact on passengers.

There was another benefit to this configuration. Using the grid approach, Structural Composites was able to use a thinner laminate for the hull. This reduced the boat’s weight, saved money and made manufacturing simpler.

However, with a less rigid laminate hull, Structural Composites needed a different surface coating. “One of the challenges that you have if you’re going to make things move around, flex and absorb energy is the gel coat,” Lewit says. Flexing in the hull or deck can crack the brittle gel coat.

With funding from Florida’s SBIR enhancement grant program, Lewit experimented with other coatings. By blending polyesters with polyurethanes, he created a coating called CoCure™ with greatly increased elongation properties. CoCure contains four components: a gel coat, an initiator, a B-side polyurethane component (polyol) and an A-side polyurethane component (isocyanate). A gel coat with no urethane has about 1.4 percent elongation. CoCure 15, a coating with 15 percent urethane, has
an elongation of 3 to 3.5 percent, and CoCure 20 has an elongation of about 10 percent. With this greater elasticity, the gel coat is more resilient and less likely to crack, says Lewit.

Structural Composites teamed up with industry partners Interplastic Corporation and BASF to develop the resin and coating technologies required to commercially produce CoCure, making it available for use in the Navy project. CoCure 20 was applied to the corners and radiuses of the 7ACC’s console, since that’s where gel coat cracking generally starts. In other sections, the project team used CoCure 15, since it didn’t need as much stretching capability.

Improvements were made to the new craft’s engine, too. The Navy typically uses inboard diesel technology to combat the risk of fire. As the 7ACC project evolved, however, engine manufacturers, including Mercury and BRP-Evinrude, began making outboard diesels. That eliminated the need for an engine-support structure, further reducing the boat’s weight. The 7ACC at CAMX, built by Willard Marine, included two BRP lightweight two-stroke, spark-fired, multi-fuel outboard engines.

With all these enhancements, the change in weight has been significant. When the project started, the 7M Navy standard rigid inflatable boat (a predecessor of the 7ACC) with an inboard diesel weighed about 5,600 pounds. Today, the latest model – the 7ACC powered with twin BRP multi-fuel engines – weighs approximately 3,500 pounds. This boat is set for fleet trials after instrumentation and offshore testing and evaluations.

In the meantime, the technology developed for the 7ACC project has benefited other applications. Wabash uses CoCure for its growing fleet of Molded Structural Composite (MSC) trailers, and Interplastic Corporation introduced new CoCure coatings to the recreational boating industry in October. Lewit hopes to see boat designs that use PRISMA components, a suspended deck and thinner hulls adopted as well. He says a combination of CoCure materials and new designs could contribute to a boat that’s up to 30 percent lighter with reduced engine sizes at costs less than current models.

The composites industry could use a breakthrough like this for the marine industry. “Other industries, like electronics, have made these great advances,” says Lewit. “It would be nice to be able to say that we’ve made boats 30 percent lighter so you don’t need as big an engine. You could actually talk miles per gallon instead of gallons per mile.”

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Silicon Valley-based AREVO, which develops technology to enable direct digital additive manufacturing of composite parts, has generated excitement with the design and production of an all-terrain city bike – the world’s first bike using a 3D-printed carbon fiber frame. The bike was the first application of AREVO’s 3D printing technology, leveraging a thermoplastic composite filament with continuous carbon fiber from Hexcel, the company’s proprietary Pathfinder software and robotics. According to the company, the thermoplastic filament is five times stronger than titanium and one-third its weight. The company completed the bike frame with only two prototypes.

AREVO’s technology aims for a more efficient and less expensive manufacturing process by integrating software early in the design to reduce the need for physical prototyping. The software allows designers to develop a digital prototype of the product prior to beginning actual manufacturing, making the process more efficient and more sustainable than traditional 3D manufacturing, according to the company.

“When you talk to a rider, how the bike feels – that is the hardness or softness of the bike – and how much it flexes under load is critical. We were able to model the desired riding quality in our Pathfinder software,” says Jim Miller, CEO of AREVO. “The software predicts the behavior and performance before the printing process begins.”

Pathfinder iterates the design based on performance parameters for tensile strength, compression, flex, shear, impact resistance and residual stress (warpage). It determines where the carbon fiber filaments need to be placed to attain the required strength without overdesigning the bike frame. A built-in patented additive finite element analysis (A-FEA) algorithm helps ensure the design meets performance specifications. If the design misses a parameter, the software adds and subtracts virtual material, reiterating the design until specifications are reached while minimizing the use of costly material.

Although the software won’t select materials, it can compare part performance based on material combinations. “We can program Pathfinder to compare the performance of a 50/50 PEEK and carbon fiber tow to the same part in aluminum or titanium, and it will indicate the trade-offs,” Miller says.

In any design environment, part changes are a way of life, and the ability to update and test designs quickly is a benefit. After AREVO manufactured the first 3D bike, it was approached by the

AREVO’s partners are excited about the ability to fabricate economically viable large-scale thermoplastic composite parts by marrying CFRP with 3D printing.
German company OECHSLER, which wanted to pair its DRIVEMATIC three-speed automatic gearbox with AREVO’s 3D-printed carbon fiber frame for an electric bike. It took one month to move the bike from concept to production, including two weeks for design and one week for printing.

AREVO’s fully automated process facilitates the production of larger parts, making the 48-inch long, 36-inch high and 2.5-inch thick bike frame an ideal first application for the 3D technology. The company says that the direct energy deposition of carbon fiber filament enables less than 1 percent voiding in the manufacturing process. “We can print large structures that exceed aerospace grade requirements for primary flight structures,” indicates Miller.

Using standard G-code, the most widely used numerical control programming language, the part design is transmitted from Pathfinder software to the production cell. The manufacturing cell consists of a 7-axis robot and platform from ABB Robotics, a deposition print head with proprietary thermal management equipment (a laser), a cutting fixture, customized electronics and a vision system for in-situ inspection. AREVO designs and builds the deposition print head themselves.

The robotic arm positions and moves the print head, which then guides the filament deposition to create the 3D shape of the bike frame. The carbon fiber material can be placed in an infinite number of orientations, according to the company.

“Flying for most 3D printers, the operator is laying down liquid material on top of a solid layer,” notes Miller. “The laser right behind the print head heats the PEEK thermoplastic so we’re joining melted PEEK to melted PEEK for tremendous adhesion strength in the inner layers of the part.” After the cutting fixture slices the carbon fiber filament, the robot repositions the print head for the next filament deposition instruction.

“The laser allows us to apply a lot of heat and deposit a lot of material very quickly,” Miller says. “On the flip side, we have to precisely control the laser to avoid burning the filament or degrading the structural integrity of the carbon fiber. Machine learning has taught the print head to see, via the visual inspection system, where and how much heat is being generated.”

The vision system monitors height, width and length. Inspecting the visual properties in real time allows AREVO to measure every layer within microns and automatically adjust via the software. “We hit the button and walk away,” says Miller.

Far beyond the world of cycling, AREVO’s partners are excited about the ability to fabricate economically viable large-scale thermoplastic composite parts by marrying CFRP with 3D printing.

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Honeycomb composite materials, often made by layering a paper honeycomb core between two thin fiberglass mats, are a well-known technology for automotive applications. OEMs have been using them for more than two decades for interior components like load floors, sunroof covers and the package shelves behind vehicles’ back seats.

But now honeycomb composites are moving outside of the interior. In China, a soon-to-be-launched electric vehicle features a hood made from a honeycomb composite with a Class A finish. A honeycomb composite is also incorporated in the removable “My Sky” roof panels in the Jeep Renegade. And the roof module for the Smart Fortwo, a two-seater city car from Daimler AG’s Smart Division, demonstrates just why honeycomb composites are drawing automakers’ attention; it is about 30 percent lighter than a previous version of the roof but has the same strength and rigidity.

Car and truck manufacturers’ ongoing interest in incorporating more composite components into their vehicles is spurring market growth, and it extends well beyond honeycomb materials. Grand View Research predicts that the global...
The automotive composites industry will reach a value of $11.62 billion by 2025, with an annual growth rate of 6.8 percent over the next seven years.

But the road to wider adoption of composites isn’t straight and smooth; there are still some difficult curves to navigate. Although composite materials can provide significant advantages in lightweighting, corrosion resistance, design innovation and parts consolidation, composites manufacturers must compete with manufacturers of aluminum and steel parts to maintain or increase their share of the parts business. At the same time, they must find ways to decrease material costs, to speed production for larger volumes and to manufacture components that are able to meet OEMs’ exacting specifications.

Composites manufacturers are continually making improvements. One example is fiberglass mats, which are used for exterior parts but are not smooth enough for paint application right out of the mold. “You have to fill it and buff it and sand it and smooth it before you can get the Class A finish, and that is an expensive and time-consuming process,” says Dan Rozelman, senior technical sales specialist in the composites and advanced applications group for equipment manufacturer Hennecke Inc.

Resin injection molding (RIM) coating technology promises to change that. With RIM, the part is put into a closed mold with a small gap left above the surface. “Then we inject polyurethane over the top to make a Class A, out-of-mold, finished part,” Rozelman explains.

Composites manufacturers produced the BMW M3’s glossy fiberglass mat hood with this process. Overmolding technology is used to make the primed surface of the part, which is then painted in the traditional manner.

To help OEMs and tier level suppliers develop this innovative coating technology and commercialize direct-from-mold Class A parts, Hennecke, coating manufacturer Votteler, Ruhl Strategic Partners and SA Engineering have opened the RIM Coating Technology Center in Livonia, Mich.

The RIM coating technology could have applications beyond the automotive industry. “It can really be applied to anything that polyurethane will stick to, and since polyurethane is a great glue, that is pretty much everything,” says Rozelman. “The main target market that is showing the most interest right now is the automotive industry for both honeycomb and injection molded parts. The secondary and tertiary markets are appliance and consumer goods like telephones, computers and small electronics.”

**Stronger Honeycombs**

Another innovation in honeycomb composites is the use of recycled carbon fiber mats with a polycarbonate honeycomb. A major OEM will use this technology to manufacture the entire underbody chassis pan of a full-size electric vehicle. The piece, roughly nine feet long, is made from four sections bonded together.

To make this honeycomb composite board, Bright Lite Structures has developed a patented polycarbonate honeycomb that is sandwiched between virgin and recycled carbon fiber mats. The mats are sprayed with a patented polyurethane-epoxy resin, and the sections are molded together using a wet compression thermoforming process.

“Polycarbonate has thermoformable properties so you actually melt and bend and flex the geometry. The sandwich structure is also very strong in certain applications, exceeding the strength of steel, aluminum or conventional carbon fiber,” says Rozelman. “You need a little bit of crush to push the polyurethane-epoxy resin through the fiber. That mushrooms the top of the straws and creates an even better bonding surface.”

For the front bulkhead section of the chassis pan, using the sandwich composite instead of a comparable aluminum design has resulted in an 85 percent weight reduction. “The aluminum piece was made in five pieces and weighed 42 kilograms [92.6 pounds]. To make those five aluminum pieces, the manufacturer...”
had to have extensive fixturing and tooling and welding apparatus and fixtures,” Rozelman says. “Using a honeycomb composite, Bright Lite Structures made the entire bulkhead out of one piece and it weighed just 6 kilograms [13.2 pounds].” The cost for the sandwich composite bulkhead was benchmarked as equivalent to that of the aluminum bulkhead.

There are approximately 300 sports cars on the road with a sandwich composite floor pan from Bright Lite Structures. Other applications the company has put into commercial production include 4.5 x 2.4 meter truck floors and commercial aircraft seatbacks that meet both the head impact criteria and fire, smoke, toxin and heat release requirements of the Federal Aviation Administration.

**More Stringent Requirements**

OEMs employ SMC for a variety of vehicle parts, including body panels for the Corvette and the hard roof top for the Jeep Wrangler. One rapidly expanding market is battery enclosures for electric vehicles, since the composite boxes are lightweight and can incorporate flame retardancy properties.

While light weight is a primary benefit of SMC parts, automakers also like that the material is compatible with the electrophoretic painting process (E-coat).

“When you have a body with metal parts, it goes through a dip process that puts on a phosphorescent coat that is corrosion-resistant,” says Mike Siwajek, vice president of research and development at CSP Plastics. Having a composite that can go through the same paint line as aluminum and steel parts is important to automakers, who want to maintain a consistency in appearance and finishes in vehicles manufactured from several different types of materials.

SMC also increases styling options for vehicle designers. “SMC has the advantage of being molded net shape, so it is possible to design parts that would be very difficult or impossible to stamp from metals,” says Siwajek.

When it comes to dimensional stability, SMC is on par with steel and better than aluminum. That makes it a good choice for semi-structural parts, like the pickup boxes for the Toyota Tacoma and the Honda Ridgeline.

At certain volumes, SMC parts cost less to manufacture than aluminum or steel parts. Siwajek says the sweet spot is generally between 30,000 to 150,000 pieces per year, since that number can be produced using one tool. If a second tool is needed, the cost advantage starts to lessen.

Although SMC is a proven technology in the automotive industry, “there are new demands every day as to what our material needs to do,” Siwajek says. “As we are growing globally, we are getting into new markets and new customers, which means new specifications and new requirements and new expectations. We have to educate people who aren’t quite familiar with what we do.”

One area of concern is the VOC requirements in Europe and Asia, which are much more stringent than those in North America. Specifications are changing all the time; Siwajek says that one European OEM recently announced that it was tightening its already tough standards. Composites manufacturers have to anticipate these changes so they are prepared for them.

“From my group standpoint, we are looking at the things that we can do with the chemistry of our materials to reduce not just the VOCs but also the use of the ever-increasing list of chemicals that are restricted,” Siwajek adds. “We try to eliminate those chemicals as we can while maintaining the surface, the cycle time, the processability and the cost.”

This calls for creative solutions. “It is a challenge, but we are meeting it and we will get there,” he says.

**Carbon Fiber Opportunities**

Producing structural automotive parts like cross beams and engine cradles presents different obstacles. One option would be to incorporate non-traditional resins like epoxy into the SMC process to provide more structure. But epoxies typically
have longer cycle times and are harder to process, so CSP is exploring new hybrid chemistries.

In addition, the company is looking at manufacturing carbon fiber parts using SMC and resin transfer molding. “Although carbon fiber is expensive, there are places where it just provides so much value. If you don’t try to cover the car in carbon fiber – if you just put it where it makes sense – you can provide cost-effective solutions,” Siwajek says. OEMs are willing to consider this option if they can realize significant weight savings while limiting waste and keeping costs down.

CSP is currently manufacturing the automotive industry’s first carbon fiber pickup box for the 2019 GMC Sierra Denali. The company is using a thermoplastic compression molding process with nylon and chopped carbon fiber for the CarbonPro box, which weighs 62 pounds less than the standard steel inner panels and floor.

In Europe, ELG Carbon Fibre is promoting the use of recycled carbon fiber (RCF) in its work with Tier 1 and Tier 2 automotive suppliers. Vehicles with RCF body panels will soon go into production there, according to Ben Andrews, ELG’s field technical services engineer.

RCF is gaining acceptance for automotive trims as well. Andrews says some OEMs prefer the appearance of composite materials that contain organic, random carbon fibers to the hard-edged, checkered pattern associated with virgin carbon fiber composites. “It’s not something that we were targeting, but we have some body panels out there and the color and trim guys saw them and were very keen on the look,” Andrews says.

While structural applications for RCF composites are limited at present, Andrews believes that will change as automakers recognize their cost savings and processing benefits. On the materials side, RCF is typically 40 to 50 percent of the cost of virgin fiber fabrics.

Reduced processing time contributes to lower costs, too. “With conventional carbon fiber materials, you have to put in lots of effort upstream for preforms and for draping with fabric,” Andrews explains. “Our reformatted, non-woven material has an inherent drapability to it, so it forms much more readily than conventional fabrics. So the drape is superior to conventional fabric and much less processing is required to
Battery enclosures for electric vehicles have become a growing market for SMC composites, which can be designed and manufactured to incorporate flame retardancy properties.

get the form that you desire.”

The reduction in RCF processing time depends on the component part. “On a really complex geometry, with virgin fabric you might have to spend a half hour or an hour getting a good preform. With recycled material, you could stamp it out in a single session of two seconds, or it may require some limited preforming. But it’s going to be minutes rather than hours or half hours,” Andrews continues.

There’s a green aspect to using RCF that automakers also like. Although there is energy involved in recycling the fiber, that energy expenditure is about 10 percent of what it takes to produce virgin carbon fiber.

**Consistency Is Key**

ELG gets its carbon fiber from companies throughout the entire carbon fiber supply chain. “The challenges have been to validate the fiber types and subsequently guarantee the material properties to the customer,” Andrews says. “We have reduced our feedstock to suppliers who are running large-scale, long-term production programs and who have a known fiber type.

A European manufacturer of a hydrogen-cell-powered vehicle will use an underbody chassis pan made from a composite honeycomb that combines carbon fiber mats with a polycarbonate honeycomb.

We use five to seven suppliers now as opposed to five years ago when we had 100 or more sources of mixed waste in low volumes.” Andrews says using fewer suppliers provides good traceability on fiber types, reduces contamination from other fiber sources and helps ensure that customers receive a high-quality product.

With this consistency of material and with the right design, automotive parts made with RCF can achieve similar mechanical performance to those made with virgin fiber.

“I think the automotive industry today has moved away from the idea of the whole body in black [carbon fiber]. The idea of a mixed-materials vehicle platform is becoming more readily accepted. It’s about using the correct materials in the correct place,” Andrews adds.

Virgin fiber is the logical choice when an automaker needs extreme stiffness, but sometimes it’s too expensive to use. Carbon fiber could be a viable alternative. “The work for us over the next years is to really identify these areas and propose our materials not only as a material savings but as a process benefit as well,” he says. “We have to work with OEMs and suppliers so they realize the benefits of the recycled fiber.”

That’s a strategy the entire composites industry needs to adopt. OEMs have many choices of materials when designing parts for the vehicles; they need to be reminded why composites are the best choice for many of them.

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During CAMX 2015, Rick Spears chatted with a friend at Oak Ridge National Laboratory’s (ORNL) exhibit. Spears’ company, TruDesign in Knoxville, Tenn., had collaborated with ORNL on coatings for the retro Shelby Cobra sports car on display, which was designed and produced in just six weeks using additive manufacturing. Displayed nearby the eye-catching car was the 3D-printed mold used to create the hood. Wowed by the Cobra, Spears’ friend suggested they go into the 3D-printed car business. Spears remembers pointing at the Cobra and saying, “That is a million-dollar business.” Then he pointed to the mold and said, “That is a billion-dollar business.”

Spears’ enthusiasm for the potential for tooling produced using additive manufacturing is shared by many in the composites industry. Vlastimil Kunc says that 3D-printed FRP tooling is emerging as “the killer application.” Kunc is team lead for polymer materials research at the U.S. Department of Energy’s Manufacturing Demonstration Facility at ORNL, which has played an integral role in developing industrial 3D print processes.

Over the past decade, aerospace and other high-tech industries have increasingly turned to 3D-printed tooling for The Next Generation of Tooling

As additive manufacturing evolves, 3D-printed tooling is catching on and taking off.

By Melissa O’Leary
speedy production, cost savings and rapid innovation. With recent advances in large-scale additive manufacturing machines, 3D-printed composite tooling is gaining broader attention.

**An Equipment Revolution**

For most of its short history, additive manufacturing technology has not been tooling-friendly. For one thing, print capabilities have been small – the first 3D-printed objects were measured in inches, and for a long time, the 3 x 2 x 3-foot Stratasys fused deposition modeling (FDM) printer was the largest on the market. According to Timothy Schniepp, director of composite solutions at Stratasys in Eden Prairie, Minn., it wasn’t until the last decade that customers began using the company’s equipment to 3D print basic molds for jigs and fixtures.

In the last four years, additive manufacturing has taken a quantum leap with the introduction of large-scale industrial 3D printers. In 2014, Cincinnati Inc. collaborated with ORNL on the world’s first large-scale 3D print machine – the Big Area Additive Manufacturing machine (BAAM™). ORNL’s website describes this groundbreaking 3D printer as 500 to 1,000 times faster and capable of printing polymer components 10 times larger than previous industrial additive machines. Two years ago, Thermwood, based in Dale, Ind., introduced the second industrial 3D printer, the Large Scale Additive Manufacturing machine (LSAM), which can print 10 feet wide, 5 feet tall and up to 100 feet in length. The scale of these new machines is extremely well-suited to 3D-printed composite tooling.

More large-scale additive machines are on the way. Ingersoll is working with ORNL to develop its Wide and High Area Manufacturing machine (WHAM) that has a print envelope of 46 x 23 x 10 feet. Meanwhile, Magnum Venus Products (MVP) is partnering with ORNL to develop an 8 x 16 x 4-foot thermoset printer, while several other companies, including Thermwood and Stratasys, are developing new large-scale printers.

Materials for additive manufacturing also are developing rapidly. In the same year that the BAAM premiered, Sabic released ULTEM™ – the first 3D printable, high-temperature material (350 F/183 C) developed in collaboration with ORNL and Stratasys. Other high-temperature materials and processes are also on the fast track to development. ORNL recently collaborated with Techmer PM to develop high-temperature thermoplastic materials and demonstrated fabrication of molds with six industry partners. Meanwhile, Polynt and Dixie Chemical are working with ORNL to create printable thermoset materials for MVP’s printer.

Moreover, large-scale additive manufacturing is no longer the exclusive territory of companies that can afford to purchase the equipment. Since 2016, when Akron, Ohio-based Additive Engineering Solutions (AES) was founded as the world’s first service bureau for large-scale 3D printing, other companies can easily access the technology. With these developments and major initiatives to adopt additively manufactured tooling underway in the aerospace industry, 3D-printed tooling can simply no longer be ignored.

**The 3D Printing Process**

Conventional tooling is typically created using subtractive manufacturing, in which a block of material such as Invar (an alloy of iron and nickel), steel, aluminum, FRP tooling board or foam is machined into a male “plug” that is then used to create a female composite mold. In contrast, 3D-printed molds are built up by rapidly depositing or “printing” beads of thermoplastic material one layer at a time. Some common thermoplastic resins used include acrylonitrile butadiene styrene (ABS), polyphenylene sulfide (PPS) and polyetherimide (PEI).

The raw material in pellet form is heated in an extruder barrel until it reaches the consistency of toothpaste. Then, it’s extruded in a horizontal pattern (on the X, Y axis) of beads. The movement of the extruder head is controlled by “slicing” software, which translates CAD files into the printing pattern. Once a layer has cooled, the print bed moves vertically (up or down along the Z axis) and a second layer is added. The process continues, adding layer by layer. Current large-scale 3D printers can lay down approximately 60 to 80 pounds of material an hour.

After printing, 3D tooling must be machined to remove the corduroy-like scallops along its edges to create a smooth surface. The molds are then sanded (typically by hand) and sealed. Finishing is generally done on a separate machine, although the LSAM has two gantries that can be fitted with either a print...
extruder or routing header, making it possible to print and mill two separate parts simultaneously.

**The Benefits of 3D Printing**

Conventional tooling can be expensive and time consuming to produce. According to Peter Hedger Jr., director of marketing and communications at Magnum Venus Products (MVP) in Knoxville, Tenn., major aerospace companies typically create tooling by milling down a block of Inconel® (nickel chromium alloy) or Invar. “That process can cost them close to a million dollars and about six months of time,” he says. Faster, 3D-printed tooling can shave days, weeks and even months off conventional tooling lead times.

Schniepp says that Dassault Aviation in Paris, which makes Dassault Falcon business jets, realized significant time savings when it began using Stratasys 3D printers to create tooling for CFRP and GFRP cabin components. “Traditionally, they would have to machine a metal mold, tooling board or glass epoxy tool,” he explains. “Those types of processes – even for a relatively small, simple shape – take a couple of months. Now, they can have a mold in a couple of days.”

The combination of materials and production speed often also make additively manufactured tooling significantly cheaper. In 2016, Thermwood and Indianapolis-based Applied Composites Engineering (ACE) conducted an experiment to compare 3D-printed tooling to conventional methods, with each company producing a tool for a Chinook helicopter drip pan. ACE used a traditional method, cutting and machining RenShape® board to create a plug and pull a female mold off it. Thermwood used its LSAM to print the mold out of GFRP with a polysulfone (PSU) matrix. The results were striking. Jason Susnjara, vice president of marketing for Thermwood, says the additive manufacturing process reduced material costs by 34 percent, reduced labor costs by 69 percent and took three days instead of eight.

In 2016, ORNL and Boeing developed a 3D-printed drill-and-trim tool for fabricating a section of the wing of the Boeing 777x. The 1,640 pound, 17.5-foot long, 5.5-foot wide and 1.5-foot tall tool was the largest solid 3D-printed object in the world at the time. A typical trim tool of that size takes significant resources and more than six months to produce, according to Kunc. Instead, the demonstration tool was 3D printed on a BAAM in about 30 hours, finished in two weeks and cost less than $20,000.

**Opportunities for Innovation**

The speed with which 3D tooling can be produced also provides opportunities for innovation. When Schniepp was employed at GE Aviation a decade ago working on FRP parts for a new Boeing program, he says that the 12- to 14-month lead time for the Invar tooling accounted for half of the 24- to 28-month long project. “We would have to lock in our part design 12-plus months ahead of first delivery just so we could get the tool in time!” he muses. “That really limits the amount of design optimization you can do…. If we had today’s technology, we would have had a lot more freedom to do additional design work and optimization.”

Faster tooling also gives companies the ability to rapidly change product designs. “Imagine that you are a boat
manufacturer. Your product is highly aesthetic, but your competition comes out with a boat that is almost identical,” says Hedger. “3D molds give you the potential to pivot in the middle of the year and produce a completely new product line without missing a beat.”

Kunc adds that 3D-printed tooling can also provide features that are simply not possible with traditional tooling, including embedded sensors and active heating elements. For example, in 2017, ORNL collaborated with TPI Composites in Scottsdale, Ariz., to additively manufacture a test mold for a wind turbine blade. Previously, the molds were created by making a plug, casting a female fiberglass mold over it and then running resistive wire across the back for heating. Kunc says the process was laborious and could result in hot and cold spots on the mold if the wires weren’t spaced correctly. “Instead, the additive process allowed us to design channels through which we could blow hot forced air to create really nice, uniform heat along the bottom of the tool,” he says.

Equipment innovations are also on the horizon. ORNL and Cincinnati are experimenting with a BAAM that has been modified to print multiple materials. Kunc says that in the future it may be possible to generate a single tool from multiple materials – for example, switching from non-reinforced polymer to fiber-reinforced polymer or from a soft structure to a rigid structure.

**Technological Challenges**

To gain widespread acceptance, 3D-printed composite tooling solutions have to address three main challenges: thermal expansion, temperature tolerance and tool life. 3D-printed thermoplastics have a large coefficient of thermal expansion (CTE), which means they expand and contract with temperature changes. Another possible issue is limited layer-to-layer adhesion. This is because while FRP beads of material bond to each other across the X,Y plane of each extruded layer, fibers don’t generally cross from one layer to the next (in the Z direction), leaving a weaker, non-reinforced bond.

Thermoplastics’ inability to bond to other materials also poses challenges. Spears worked with ORNL and Polynt on coatings for the first-ever, large-scale composite mold – a demonstration CFRP car hood. The mold was 3D printed on a BAAM in eight hours and gel coated. However, when they removed the hood from the mold, the tooling gel coat came off with it. With then President Obama and Vice President Biden visiting the next day, Spears says, “We pulled an all-nighter, sanded the gel coat off the hood and got it to work.”

Since then, multiple coatings have been developed to address these challenges, including TruDesign’s new TD Coat RT, a high-build, sprayable thermoset tooling coating developed in collaboration with ORNL and Polynt and released last year. Kunc says that future coating advances are crucial to the development of 3D-printed tooling. “In tooling, it is about the surface,” he says. “The underlying structure may be 3D printed, but there is a lot of work to be done in how you treat the surface.”

Temperature tolerances have created another challenge. Until recently, 3D-printed tooling applications were only suitable for low-temperature parts. As noted earlier, Sabic’s ULTEM was the first high-temperature 3D-printable material to reach the market. Last year, Techmer PM introduced Electrafil® PPS 3DP and Electrafil® PPSU 3DP high-temperature autoclave tooling materials for composite part production developed in collaboration with ORNL and BASF. Other companies are also racing to develop high-temperature, low thermal expansion solutions for additive manufacturing, including Stratasys and Magnum Venus Products, which is collaborating with ORNL, Polynt and Dixie Chemical to develop an industrial 3D printer and thermoset materials.

Tool life is another issue. For most applications, 3D-printed tooling has a much shorter lifespan than conventionally manufactured tooling. To date, most 3D-printed composite molds have been used to create well under 100 parts. Some conventional tooling can last for thousands – even millions – of parts.

Short tool life cycles mean that, for now, 3D-printed tooling can’t compete with metal tooling for high-volume production. Low-volume production, however, is a growing sweet spot. Consider Dassault Falcon Jet’s
FRP printed cabin components. Schniepp says that because business jets are highly customized, the company may only need to build a handful of interior parts at a time. “So, they don’t need a mold that lasts thousands of cycles,” he points out. “They need something immediately that lasts for five [parts]. That’s where 3D printing fits extremely well.”

Schniepp says that even with shorter tool lives, the speed to produce 3D-printed tooling could lead to a shift away from traditional manufacturing programs that use metal tooling to produce thousands and thousands of parts. “You can now economically produce 50 of one product and then 100 of something different, versus locking yourself into producing the same product for the next 30 years,” he says.

What’s on the Horizon?

3D-printed composite tooling is in its infancy. Schniepp estimates that less than 100 of Stratasys’ 50,000 installed industrial printers are being used for composite tooling, while Kunc surmises that there are only about 20 large-scale 3D printers installed throughout the United States.

As a result, adopters of the new technology are simultaneously using it and helping to develop it. Andrew Bader, co-founder of service bureau AES, admits that while the company recently reached a milestone of 300 prints, about half of the company’s business is manufacturing tools and parts for customers and the other half is working on the technical process to improve the printing technology and applications. “We’re working with brand new technology,” Bader explains. “We always laugh and say, ‘There’s no manual for this!’”

Despite the growing pains, 3D-printed composite tooling is on the rise. All the major aerospace companies have 3D-printed tooling initiatives underway, and many newly purchased large-scale additive machines are being used to print tooling. Two out of three of the LSAM installed to date have been purchased for tooling – one for sand casting and another for aerospace tooling. “The technology is spreading on its own,” observes Kunc. In other words, the “killer application” is taking off.

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Get the Most from the M&A Process

Strategies for maximizing the value gained through mergers and acquisitions.

By Megan Headley

This has been a big year for merger and acquisition (M&A) shake-ups across the composites sector, and it's easy to see why.

“The composites supply chain is very fragmented,” says David Horner, CEO of Applied Composites Holdings LLC, an aerospace and defense composites supplier. “There are a lot of smaller-scale players competing with very large players and very few medium-size organizations. There’s a real opportunity for consolidation, and it brings some strategic opportunities to those companies that pull together to find ways to be more competitive.”

From his aerospace perspective, Horner is watching large OEMs vertically integrate to bring needed capabilities and materials in house. “Very large OEMs are going to be nervous about putting a large amount of work into very small organizations, so that also is going to drive the need for consolidation and creating greater scale in the supply base,” he says.

Composites companies entertaining the idea of a potential merger or acquisition, from either side of the table, should make sure they’re prepared to maximize the value they get from a deal.

Finding the Right Steward

Michael Del Pero, managing director of FocalPoint Partners LLC, an investment bank with expertise in composite industry M&As, sees two primary drivers behind industry acquisitions: Acquirers are looking for deals to land either innovative materials technology or specific manufacturing capabilities. When it comes to the former, he notes, “That’s where you sometimes see smaller businesses trade at pretty high valuation because a buyer, like PolyOne for example, [recognizes] how they can leverage their global network of sales, distribution, etc. and take a small but sophisticated material technology and turn it into a much bigger product in their portfolio.”

Joel Rathbun, senior vice president of mergers & acquisitions for Cleveland-based PolyOne, describes acquisitions as pivotal to the company’s growth strategy. The company has purchased four composites companies over the past five years: Glasforms Inc., Polystrand, Gordon Composites and, most recently in June, PlastiComp Inc. “These were all headed by owner entrepreneurs who were looking for good stewards for their companies,” Rathbun says.

That level of experience has taught PolyOne how to position itself in the M&A market. “We’ve built our capabilities so that we become the buyer of choice: we’re efficient, collaborative and have a track record of closing deals successfully,” Rathbun says. “Our deep resources, commercial excellence, invest-to-grow strategy and global reach are all part of this capability structure.”

Prospective sellers should carefully consider what they expect
from their buyer of choice, particularly, as Del Pero points out, because many sellers within the market speak to only one potential buyer and stop the process there. “A lot of the deals that we’ve seen in the market have been done on an unbanked basis, meaning an owner just consulted for himself or was approached one-off by a buyer and said, “That sounds good to me; let’s do it,’’ he says.

However, that type of deal may leave significant value on the table, Del Pero cautions. On unbanked deals in the composites industry, Del Pero sees valuation multiples between seven to nine times EBITDA (earnings before interest, tax, depreciation and appreciation), which is fairly good compared to some other industries. (Del Pero explains EBITDA as “effectively, operating cash flow.” So, if a company is making $10 million in EBITDA per year and it sells for eight times, then it sells for $80 million.) But for banked deals, where an investment banker is involved in the process, valuations in the composites industry may range from nine to 11 times EBITDA – sometimes higher.

“If you do it the right way, you can tell the story the way you want to tell it,’’ Del Pero explains. “You can stage the information in a way that is strategically beneficial. But most importantly, you’re able to create what we call a ‘competitive auction process.’” In such a scenario, your company is attractive to multiple potential buyers.

Another consideration is the buyer’s intent after the acquisition. “Do you want a strategic buyer who will invest in the company or a financial sponsor who may want to sell the company in the short term?’’ Rathbun asks. “Our best transactions have resulted from developing a relationship early with the owners and management team and negotiating a transaction in an exclusive process that meets the goals of both parties.”

Del Pero encourages companies to thoughtfully consider several questions in the search for the right steward for their business: “Do you know what you’re really getting? Do you know what the market will bear? Do you know that you’re getting not only the best price for your company, but the best terms and conditions?” The answers to these questions should help direct sellers to the right buyer.

**Integrating Corporate Cultures**

Private equity firm AE Industrial Partners (AEI) formed Applied Composites through its acquisitions of AC&A in 2016, Applied Composite Engineering and Applied Composite Structures (formerly EnCore Composite Structures) in 2017, and San Diego Composites (SDC) earlier this year. From that experience, Kirk Konert, principal with AEI, can say, “Every acquisition is a little different.”

AEI has worked to become a buyer of choice through its high focus on culture. “We want to highlight the great things that have made the company what it is today and not disturb or disrupt what a founder or a family has built,’’ Konert says.

That focus on culture was important for SDC. While SDC did not work with an investment banker, it built a close relationship with AEI through partnering together on projects. “They knew us well, and they were comfortable with the team. We came to a deal on terms in early November, and we ended up closing in early February, so it was a 90- to 100-day process from start to finish,’’ Konert says.

The SDC acquisition transpired a bit differently than other deals for AEI. “Some companies will spend several months getting ready for an acquisition process with an advisor, making sure they have all their financial information in order and ready to go. SDC was different in that we basically worked together to get the materials needed ready to go for our due diligence,’’ Konert explains.

Discussions during the acquisition included making sure that integration plans were in place, that everyone agreed on the terms of what the company would look like post-acquisition and how the business processes would fit together.

In taking this approach – of building a large footprint in the composites industry from four separate strategic acquisitions – a well-planned integration process has been critical. That begins early on with communication with employees about what’s to come.

“One thing you’re dealing with a lot of change – whether it’s changing leadership, changing ownership or changing markets – getting up in front of the employees, having a dialogue and keeping them informed will minimize concern or fear on their end,” Horner says. “You should probably be striving for over-communication because employees are going to be worried. ‘Who is this new group? What’s the long-term plan? How does it affect my family?’”

Shane E. Weyant, CEO and president of Creative Pultrusions
Jerry Miller, left, outside sales representative, and Michael Gassler, lean/ISO manager, for Creative Pultrusions discuss profile design and quality control.

Shane Weyant, president and CEO of Creative Pultrusions, leads a discussion with members of the management, marketing and sales department on strategies for reaching monthly goals.

Inc. (CPI) in Alum Bank, Pa., points out that a focus on working with companies with a similar culture can also help ease the intrinsic challenges of the M&A process. In 2017, CPI acquired Kenway Corporation, a composites manufacturer it had worked with through the years as both a customer and a vendor. The two firms shared values, business philosophies and a vision for the future of the industry.

“Make sure you understand the culture of the company to make sure both groups are a good fit. Changes will occur and depending on the size of the company and structure, such changes will be a challenge for both groups,” Weyant says. “We look for groups that fit our overall strategic growth strategy and companies that fit our cultural style.”

The integration process will include many different elements, ranging from external activities such as branding to internal activities such as looking at costs and reducing redundant activities across organizations. For example, Horner says, “There’s a lot of overlap in the types of materials that are purchased, everything from packaging to raw material, so that creates a lot of synergy opportunities.”

Overlapping activities can also generate competition across sites within a company. “Making sure that the individual sites are not competing against each other for the same opportunity is the real key aspect to integration,” Horner adds. He advises looking closely at the sales and marketing process and the pipeline of new opportunities to identify redundancies.

Of course, all of these activities can benefit from having the right people in place to identify opportunities.

Putting Together a Team

Compiling the right team can create value at every step during a merger or acquisition.

“This industry in particular has a tendency to try to do a lot of stuff on its own without seeking outside help,” Del Pero finds. Yet, as he is quick to add, “Anybody that’s looking to go through some sort of a transaction needs to get the proper outside help. Don’t try to do it yourself. You invariably will make life more difficult for yourself or leave some value on the table.” As Del Pero says, you wouldn’t try to sell your house without a realtor. Similarly, you shouldn’t tackle an acquisition without a guide.

In performing due diligence, Konert emphasizes the importance of having the guidance of a strong financial person – whether that’s a CFO, an outside auditor or a trusted accounting advisor. “Usually the initial focus of the diligence is around the financials and making sure that corroborates with the valuation. So having a strong advisor, whether that’s internal or external, who has experience getting ready for a sale process from a financial standpoint is key to having a leg up in terms of getting a deal done faster,” he says.

Weyant recommends engaging external professionals in legal, financial, tax, environmental and commercial areas during the due diligence stage. “Such resources are the experts and can help uncover any issues associated in the acquisition process,” he says.

From either side of the deal, it’s important to understand who will lead the company into its next phase. “If you have an owner that’s looking to exit the business after he or she sells it, leaving a void of leadership, you’ve got to look at the decision-making capability within the business,” says Horner. “If there’s potential for a leadership void, the acquiring company needs to more thoroughly assess the remaining management resources to ensure the business can run effectively post-acquisition.” Rathbun says it’s helpful for companies to have a “strong second level of management in place – financial, operations, sales and human resources.”

The leadership question is one that should be held early on between companies. “Be open and candid about the role of the owner post acquisition, i.e., their desire to stay engaged or move on to other endeavors,” Rathbun says. “The acquiring company should consider all requests and be open and candid as well.”

Preparing for Sale

While the M&A process can take a year or more, there is lots that a company can do to prepare in advance to speed the process to the desired conclusion. “If you want a structured outcome then you need a structured process. Start early and consult with professionals that can help you get through this,” Del Pero says. He advises beginning conversations with your team of advisors one to two years prior to going to the table to sign a deal to make sure your financial house is in order.

Horner suggests that business owners looking to sell start focusing on accounting systems early and begin the steps of the
financial due diligence process to have clarity in the process, including the following:

- Understand revenue and profit by product and by customer
- Bring the company into the discipline of month-end financial closings
- Ensure the financial systems are GAAP (Generally Accepted Accounting Principles) compliant
- Conduct year-end external audits

Horner says that going through these steps can be beneficial for smaller organizations that are preparing for the M&A process. Just as shoring up your financial house is important, Weyant also recommends conducting environmental due diligence to ensure your safety processes are sound.

With the right foundation prepared, the letter of intent provides one last opportunity for a seller to establish expectations about the future of their company. Also known as a term sheet, a letter of intent documents the expectations of both the buyer and the seller during a transaction. The letter is a crucial step in aligning expectations concerning the timing of the deal, pricing and how the future company will look. It gives the potential buyer exclusivity to work with the seller without the distraction of other potential buyers, and it provides the seller the option of confidentiality around additional information they may want to share with the buyer.

Thorough preparation for the M&A process can help keep disruptions to a minimum. This is particularly important because, as Horner puts it, it’s safe to assume that business won’t run normally during and immediately following the transaction. “An integration or acquisition requires a significant amount of focus,” he says. “People need to really be aware of the change that’s going to happen to the business.”

But the rewards – a smooth deal that brings true value to both parties – should make the work worthwhile. Del Pero concludes, “You’d much rather sweat a little bit in peace then bleed in war.”

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Through committees dedicated to specific market segments, ACMA works to increase the use of composites by opening new markets and expanding existing ones. Lend your voice and expertise to our Composites Growth Initiative (CGI) committees, and work with other committed professionals to help grow the industry. There are 10 committees that meet bi-monthly and cover a variety of market segments, from architecture to transportation structures. To join a committee, go to https://acmanet.org/composite-growth-initiative-overview/.
Best Practice for Workplace Safety

By John Schweitzer

What is best practice for workplace safety? Does it entail hard hats, respirators, Tyvek® suits and safety glasses? Intensive training programs? Warning signs and yellow stripes on the floor? An effective safety program can certainly include these components. But according to research cited by the Occupational Safety and Health Administration (OSHA), companies with the best record of workplace health and safety employ safety management programs based on three principles: management leadership, worker participation and a systematic approach to finding and fixing hazards.

According to OSHA, and the experience of ACMA member companies, these programs do the following:

- Prevent workplace injuries and illnesses
- Improve compliance with laws and regulations
- Reduce costs, including significant reductions in workers’ compensation premiums
- Engage workers
- Enhance social responsibility goals
- Increase productivity
- Enhance overall business operations

In addition, industry-wide adoption of workplace safety management programs may allow OSHA and state agencies to focus enforcement and rulemaking activities elsewhere.

ACMA’s recently introduced voluntary ACMA Workplace Safety Management Program is designed to help composites manufacturing facilities achieve workplace safety best practice following OSHAs recommended approach. Facilities participating in the program agree to make continuous progress by adopting certain practices such as development and implementation of a written safety program, responding to and preventing future incidents, and reviewing available information on the health hazards and physical risks present in an operation.

Written Safety Programs

To participate in the ACMA program, composites manufacturing facilities agree to develop written safety programs that:

- Are developed and implemented by a team that includes employees at all levels of the organization.
- Address all the health risks and physical hazards known to be present.
- Reflect the best reasonably-available information about hazards and risks, including from sources outside the organization.
- Include the review and response to workplace safety incidents, including near misses.
- Use regular safety inspections by a team of employees to review compliance with procedures and identify needed improvements.
- Include a management-of-change program that evaluates the health and safety impacts of any significant change in materials or processes.
- Provide comprehensive training of all employees, including refresher training.
- Conduct an annual review of the effectiveness of the written safety program and opportunities for improvement.

Many composites manufacturers already have programs employing many of these elements. To participate in the ACMA program, a facility only has to agree to make year-to-year improvement in its safety effort, starting with where it is now.

Worker Participation Is Key

Research indicates that out-of-the-box safety programs or programs mandated from C-level executives are not effective. They sit on office shelves (or computer drives) collecting dust.

What’s common among the most effective programs is that they are developed and implemented by teams composed of employees at all levels of the facilities. ACMA’s program provides overall program goals, suggests elements and approaches to develop programs, and links to helpful resources. But it’s critical that the written program for a facility be developed by the employees who will have responsibility for implementing it and who will directly benefit from improved workplace health and safety.

To get started, the plant manager or other company official responsible for operations at a facility might find it helpful to start with the following steps:

- Appoint a team within the facility that will be responsible for development and implementation of the program.
- Communicate clear expectations for performance of the team, and describe the resources that will be made available.
- Direct the team to use a plant diagram to start locating and describing health risks and physical hazards.
- Identify which member of the team will be responsible for using internal and external resources to collect and summarize information about risks and hazards.
- Set a schedule for team meetings with implementation milestones, such as completion of first draft of written program, implementation of incident reporting and response, etc.
• Use the implementation milestones to pace progress. Continuous improvement is the criteria for a successful program.

Accessing ACMA’s Program
The Workplace Safety Program section at the MyACMA portal (https://myacma.acmanet.org) provides the following resources:

• Required program elements
• A participation agreement for access to additional resources and recognition
• Typical program elements for composites manufacturing operations
• Additional resources, including a summary of applicable standards and regulations

Further resources are available in the Safe and Sound program section of OSHA’s website (www.osha.gov/safeandsound).

John Schweitzer is senior advisor to the president at ACMA. Email comments to jschweitzer@acmanet.org.
In the CAMX Live! opening general session, Charles Kuehmann hit on themes that resonated with the room full of composites and advanced materials professionals. As vice president of materials engineering for both SpaceX and Tesla Motors, Kuehmann talked about the companies’ missions – displacing the combustion engine, as Tesla strives to do, and bringing colonists to Mars, which is SpaceX’s goal. While these may seem like lofty goals, the focal points to get there are deceivingly simple – and ones most industry professionals can likely benefit from at their own companies. They include placing an emphasis on material selection, sustainability, lightweighting, design engineering and collaboration.

Kevin Barnett, ACMA Chairman of the Board, reflected on Kuehmann’s message after CAMX Live! “Many of us may not be in aerospace or automotive, but it’s more about possibilities – creating opportunities to do things that maybe you hadn’t thought of before.”

**Material Selection** – Whether designing the latest Tesla automobile or a spaceship, material selection is key. SpaceX is currently developing BFR, a fully reusable vehicle designed to orbit earth, as well as travel to the moon and Mars. “Where we are going with the BFR is a complete and utter leap from [previous SpaceX] technologies,” said Kuehmann, “and it’s going to require a lot of materials technology to make that happen.”

The company is starting to build the first pieces of hardware for the 118-meter tall, 9-meter diameter space vehicle. The first layup

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made for the BFR system was a 9-meter carbon fiber cylinder. “Not only is it a challenge to make something this big. This is a composite that is going to operate with liquid oxygen and liquid methane, so the systems have to be compatible with those types of temperatures and the oxygen environment itself,” said Kuehmann. “There’s a lot work actively going on developing these material systems, their processes and methods to lay these [materials] down, cure them and make a high-strength composite.”

Sustainability – SpaceX is not simply concerned with building a rocket to reach Mars; it’s also focused on creating a completely self-sustaining colony so people can live there. Material and component recycling and reuse will be crucial for life on Mars. “Everything that we build or make we are going to have to reuse because it’s very expensive to bring anything else out there with us,” said Kuehmann. “So things like 3D printing, flexible manufacturing and recycling strategies are very, very important, and they are all things we’re working on.”

Lightweighting – Tesla’s goal is to accelerate the world’s transition to sustainable energy. “Transport is one of the few places where non-sustainable energy has been hard to displace,” said Kuehmann. “We can use sustainable energy in our homes and in our businesses. But it’s been very difficult to allow sustainable energy to take over transport systems.” Tesla is taking on commercial transport with its Tesla Semi, which has a number of prototypes under development. “Even though it’s a big truck, weight is really the big driver,” said Kuehmann. “Every kilogram of weight we have in the vehicle or in the battery pack takes a kilogram out of the potential payload capacity.” Tesla is looking at advanced technologies, including sheet molded products and other composites, to reduce weight in the body structure, the enclosures and the battery systems.

Design Engineering – The Tesla Model 3 utilizes aluminum, mild steel, high strength steel, ultra-high strength steel and composites. “Not only is this about getting the right materials where we need them, but this kind of approach [requires] looking at the joining technologies,” said Kuehmann. “When I talk with the design teams when we start these projects, I say, ‘Let’s start at the joints, and we’ll design the car out from there.’ That’s how much emphasis you have to put on the joining technologies.” The team uses both advanced castings and advanced composites to integrate more of the body structure into fewer parts with fewer interfaces.

“We are taking an approach at both [Tesla and SpaceX] that really makes materials engineering part of the overall design and engineering function,” said Kuehmann. They do that with a technique called integrated computational materials engineering (ICME), where they design a part and material together using process simulation software along with material modeling capabilities to create the whole system. “That’s where the power comes from,” said Kuehmann.

Collaboration – The projects at SpaceX and Tesla all have one thing in common: They require teamwork. “One of the benefits of working in both groups is that we can utilize people across those teams,” said Kuehmann. “We do collaborate regularly.”
ACMA Sees Strong Membership Interest at CAMX

The ACMA booth was the place to be at CAMX as members, member prospects and other attendees came by to inquire about ACMA programs, ask advice about technical and regulatory issues, check on the schedule of upcoming events, training and certification, and of course, become members of ACMA. More than 120 individuals representing over 75 companies visited the booth, and staff conducted pre-scheduled appointments and interviews with 18 top prospects. ACMA’s certification/training program (CCT) was a popular subject of inquiry, as were the upcoming OEM Technology Days. The membership team was strongly supported by Composites Growth Initiative, marketing and government relations staff, who answered attendee questions at the “Ask the Experts” table at the booth. If you need updates on upcoming ACMA activities and programs, contact the membership department at membership@acmanet.org.

Statement of Ownership, Management and Circulation
(Required by 39 USC 3685)

1. Title of Publication: Composites Manufacturing
2. Publication Number: 2367-1
3. Date of Filing: Oct. 11, 2018
4. Issue Frequency: Bimonthly
5. Number of Issues Published Annually: 6
6. Annual Subscription Price: $0
8. Complete Mailing Address of the Headquarters or General Business of Publisher: Same
11. Known Bondholder, Mortgagees and Other Security Holders Owning or Holding 1% or More of Total Amount of Bonds, Mortgages or Other Securities: None
12. Tax Status (for completion by nonprofit organizations authorized to mail at special rates): Has not changed during preceding 12 months
13. Publication Name: Composites Manufacturing
14. Issue Date for Circulation Data: Oct. 1, 2018
15. Extent and Nature of Circulation; Average No. of Copies Each Issue During Preceding 12 Months; Actual No. Copies of Single Issue Published Nearest to Filing Date
a. Total No. of Copies (net press run): 8481; 9665
b. Paid and/or Requested Circulation:
   (1) Paid or Requested outside County Mail Subscriptions Stated on Form 3541 (include advertiser’s proof and exchange copies): 7710; 9489
   (3) Sales through Dealers and Carriers, Street Vendors and Counter Sales and other Non-USPS Paid Distribution: 250; 250
c. Total Paid and/or Requested Circulation: 7960; 9734
d. Non-requested Distribution:
   (1) Outside County Nonrequested Copies Stated on PS Form 3541: 150; 150
   (4) Nonrequested Copies Distributed Outside the Mail: 250; 250
e. Total Nonrequested Distribution: 505; 505
f. Total Distribution (sum of 15c and e): 8465; 10,244
g. Copies Not Distributed: 50; 50
h. Total (sum of 15f and g): 8515; 10,294
16. This statement of ownership will be printed in the November/December 2018 issue of this publication.
17. I certify that the statements made by me above are correct and complete. Signature and title of Editor, Publisher, Business Manager or Owner: Thomas Dobbins, Oct. 5, 2018
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