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Corvette rear bumper beam: CURVED, PULTRUDED PROFILES

MAY 2020

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VOL 6 No 5


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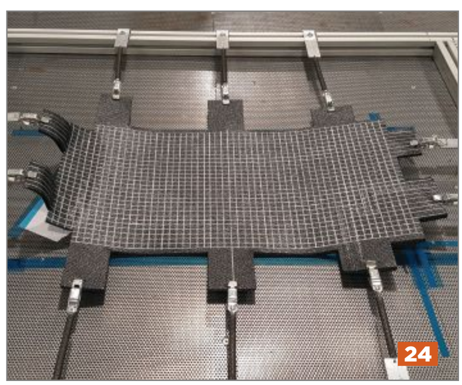
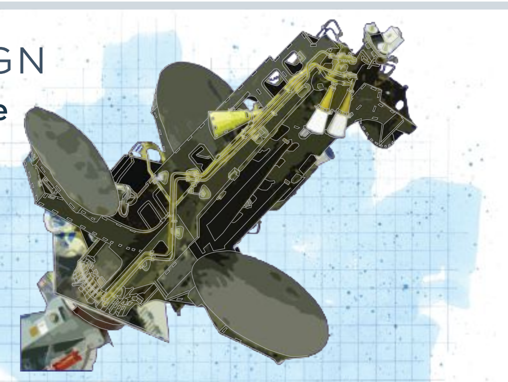


ON THE COVER

Following installation of bracketry, a six-axis robot transports the finished carbon fiber composite bumper beam for the 2020 *Corvette* to a final quality inspection station prior to shipment to General Motor's Bowling Green, Ky., U.S., assembly plant.

Source / Shape Corp.

FOCUS ON DESIGN



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» As humans, we have the unique ability among all living creatures to comprehend the passage of time and use that comprehension to help us develop some understanding of the future. That is, we use information about the past and the present to generate predictions about the future. The vast majority of the time, this past-present-future consciousness works pretty well — or well enough that we can ably navigate events as they unfold in front of us. We do this as individual persons and collectively as communities, cities, companies, organizations, nation-states and humankind.

We already have the tools needed to craft our future.

Our ability to project into the future, however, founders when we are confronted with unanticipated events, or when we are faced with events that do not have a recent historical corollary that allows us to predict what might happen next. In the current coronavirus pandemic, we are facing an unanticipated event that also has no recent historical corollary.

If you were like me, as work, travel and physical distance restrictions were implemented throughout March and April, you immediately scrapped the future mindset you previously held. You then attempted to build a new anticipated future based on how you thought the pandemic, restrictions, an economic shutdown, vaccine development and eventual recovery might play out.

The problem is that we are building this prediction with no recent historical corollary. Yes, I have heard analysts refer to the 2008-2009 Great Recession and 9/11, but neither of these events is a helpful guide. The Great Recession unfolded over several months and, although it was debilitating for millions of people, it did not result in an abrupt and nearly total shutdown of global economic and social systems for several months. The 9/11 attacks, although immediate and shocking, caused the cessation of *some* air travel for only a few days and produced relatively mild economic fallout.

If you're looking for a *pandemic* corollary, you have to go back to the 1918 flu pandemic, which infected 500 million people and killed 50 million. There are, however, a few problems if we want to use the 1918 flu pandemic to inform our view of the COVID-19 outbreak. First, we have no real memory of this event; there are few people alive today who can tell us what the 1918 flu pandemic was like. Second, the world of 1918 hardly compares to ours: There was no automotive industry (to speak of), there was no aerospace industry, the option of working from home was nearly nonexistent and governments did not impose the same travel and contact restrictions we have today. On top of that, the healthcare industry in 1918 had no way to beat the flu virus — whether you lived or died was up to your immune system only.

So, here we sit, each ensconced in our homes, facing a rare and unanticipated global pandemic for which we have no history to help construct a feasible and sensible future. Each of us is forced to contemplate vague but possible outcomes for ourselves, our parents, our children, our friends, colleagues, our communities and our countries. We are also forced to contemplate possible outcomes for the composites industry.

Those outcomes seem varied, depending on the market. The commercial aerospace market, for example, clearly seems headed for a once-in-a-generation paradigm shift created by the unprecedented and sudden grounding of nearly all global passenger air travel. Similarly, the automotive industry is headed toward a couple years, at least, of depressed demand for new cars and trucks. On the other hand, the wind energy and industrial end markets appear, so far, to be weathering the pandemic well and could drive industry growth through the downturn we are sure to face.

Ultimately, however, our ability to envision a post-pandemic future might depend less on our past and more on our present. Baked into the composites industry — today — is a level of innovation, adaptability, vision and dynamism that conveys to each of us inherent advantages that are sure to help see us through the uncertain and fuzzy future we face. We already have the tools needed to help us craft our future, even if we do not yet know how and where those tools might be deployed.

So, as you consider the change wrought by the pandemic, and as you consider your present situation, I ask what tools you think will be most necessary and most effective in the coming months. I ask you to look ahead to May 1, 2021. What do you think are the strategies and tactics — business, design, materials or process — that will help you and your business successfully navigate the next 12 months? Send your thoughts to me at jeff@compositesworld.com. We will aggregate and publish the feedback I receive.

JEFF SLOAN — Editor-In-Chief

Developing new solutions for noise, vibration and harshness

» IACMI — The Composites Institute (Knoxville, Tenn., U.S.) and its project partners have been making significant progress over the past five years in areas already discussed in previous columns this year. Another focus for IACMI projects is reduction of noise, vibration and harshness (NVH) in automotive applications.

Despite enabling energy savings and emissions reductions from reduced fuel use, automotive lightweighting can contribute to unfavorable NVH in vehicle operation. NVH is most commonly managed through absorption of acoustic energy by physical structures. The comparison of effectiveness of energy absorption between materials is determined by complex relations between physical and design factors, such as mechanical properties, density and intrinsic structure, as well as component geometry, connections and loading. Vehicle mass reduction can be a zero-sum game for automakers in cases where a light material is directly substituted in an existing design, but *additional* mass is required to meet NVH requirements. Addressing NVH early in the design for a new material can help realize a positive impact on weight, cost and energy.

With respect to IACMI's goals, NVH challenges directly impact the overall cost of deploying carbon fiber-reinforced polymers (CFRP). While NVH challenges are embodied in passenger sound and ride quality in automotive applications, acoustic energy can also negatively impact rotor rotation speeds in wind turbine applications. Managing NVH costs is easiest if addressed early in product and process design using predictive modeling tools and integrated design approaches.

IACMI and its members have identified a range of topical focus areas important for achieving IACMI's technical goals while also addressing NVH challenges:

- *Novel fabrication techniques and advanced lay-up methods* can enable highly tailored structures and fiber orientations that improve NVH quality in composites.
- *Comprehensive simulation tools and software suites* can help address NVH challenges throughout the composite lifecycle — from design, to validation, initial manufacture, use through end-of-life (EOL), recycling and reuse.
- *Dynamic material and structural characterization methods* improve the accuracy of predictive modeling tools to better control NVH performance costs during early design stages.
- *Systems-level design and process modeling approaches* permit greater control of early-stage NVH performance through concurrent simulation-based experimental design of materials, components and structures, and their respective manufacturing processes.
- *Multimaterial design methods and joining technologies* can simultaneously permit the selective integration of new high-performance composites while helping to solve core NVH issues.
- *Unique fiber architectures, additively manufactured structural cores and embedded sensor technologies* can help solve NVH issues in automotive and wind applications.

To help guide industry-led technology demonstration projects toward achievable NVH solutions, IACMI and its members co-developed a strategy with these objectives:

- *Align NVH project proposals with industry needs.* Industry stakeholders recognize that increased NVH performance helps boost the adoption and market pull for advanced composites. IACMI will continue to support project opportunities that propose to solve core NVH challenges and reduce downstream change-related costs.
- *Proactively address NVH in early product and process design to reduce change-related costs.* Integrated design approaches that combine predictive modeling tools with dynamic material/structural characterization approaches can help composites manufacturers proactively control NVH performance costs during the early stages of product design. Demonstrating these cost savings will help promote and accelerate adoption of composite materials in automotive and wind turbine applications.
- *Leverage IACMI's unique vertically integrated partnerships.* NVH challenges are driven by many systems factors, including multi-component composites structures, adhesives, and intermediates, and their respective manufacturing processes. IACMI will continue to facilitate collaborative relationships across the composites manufacturing supply chain to address key NVH needs while delivering lighter composites for automotive and other application markets.

Considering all aspects of advanced composites integration in novel ways — such as how NVH impacts the vehicle and user experience — is important for the implementation of composites into the automotive market. Through better understanding the factors that impact NVH, IACMI can lead industry research to solve problems and continue to drive lightweighting of the automotive sector. CW

ABOUT THE AUTHOR

Uday Vaidya serves as director of the University of Tennessee's Fibers and Composites Manufacturing Facility (FCMF), as IACMI's chief technology officer, and is the University of Tennessee-Oak Ridge National Laboratory governor's chair in advanced composites manufacturing. Vaidya is an expert in manufacturing and product development of fiber-reinforced polymer composites. Vaidya serves as the editor-in-chief for Elsevier's Composites B: Engineering journal. He engages a broad range of undergraduate and graduate students in experiential learning with composites technologies.

Musings from a (social) distance

» As I write this I am, like much of the world, in week three of the "stay at home" or "shelter in place" mode necessitated by the COVID-19 coronavirus pandemic. And I, like everyone else, am asking the same questions. When will this end? When will life return to "normal"? The answers to these questions are elusive as we struggle to measure either exactly where we are, or in which direction we are heading. It reminds me of Heisenberg's Uncertainty Principle, or the indeterminate state of existence represented by "Schrödinger's cat" from my university quantum mechanics classes. Both concepts relate to the difficulties in measuring the exact state of matter.

> One outcome of this crisis may be a more balanced discussion regarding the benefits of polymers.

I am convinced that the new term of the year, when 2020 ends, will be "social distancing." If we don't spend a lot of time in groups, as humans are wont to do, we stand a chance to reduce and possibly overcome the spread of the virus so that it struggles to spread and dies off. Implementation of social distancing has changed how we work, how we communicate and how we collaborate in the composites industry. Many of us are working from home, something I have done for the most part since 1993, so I am fairly comfortable doing it.

Up to a point, that is. I cannot recall a time in the last decade, and maybe longer, where I've spent three weeks straight in my home office, much less what I believe will be at least several more weeks. I'm a social creature and feel like I work and learn best in real person-to-person situations, necessitating travel, hotel stays, attendance at conferences and other physical events. The virtual world, while useful, is no substitute for seeing and touching composite materials, parts and assemblies. In the first month alone, I have had to cancel travel to multiple conferences and events, not to mention trips to corporate headquarters and partner sites. Sadly, 2020 will be the first year since 2000 that I won't make the annual spring pilgrimage to Paris for the JEC World exhibition to see the latest in composites innovations.

I'm not alone. I've had dozens of calls with contacts in the industry over these last three weeks and we are all in concert – we are getting some form of "cabin fever" and are looking forward to getting back to our nomadic normalcy. We'll do our part to get through this, but we will be the first ones to hit the road as soon as the all-clear signal is given. I know there will be a lot of "catching up" to do during the busy fall conference season!

The current crisis is forcing some rethinking of past decisions. Last month, I wrote about the growing need for sustainable composites manufacture, a need which grew out of widespread bans on single-use plastics in numerous communities and some countries. Today, however, as a result of the pandemic and with concerns over hygiene, retailers are telling customers to leave their potentially unsanitary reusable shopping bags and containers at home, and reintroducing single-use plastic bags, utensils and beverage cups. While it is tempting to say, "we told you so," we still need to make the effort to reduce plastic and composites waste, with a focus on a circular economy. I am optimistic that one outcome of the current crisis is a more balanced discussion between all parties regarding the benefits polymers in all forms convey to humans and the planet, and how best to address polymer disposal and reuse, rather than simply banning them outright.

Previous decisions about global sourcing and supply chains are being questioned, especially as they relate to personal protective equipment like masks and gowns, but also to sophisticated assemblies like respirators. We clearly live in a globally interdependent society, and innovation can come from anywhere, but I suspect governments will move to invest and encourage greater domestic sourcing of many critical technologies, including those that involve composite materials.

While the above are some of my personal observations, they no doubt resonate with many of you. While there is likely to be a new version of "normal," I am confident we will emerge from this crisis with renewed enthusiasm to bring innovative composite solutions to market. I am also hopeful that by the time you read this, the worst of the pandemic will have passed, and we have some insight as to when we might resume face-to-face interactions. One thing is certain when we all meet again at industry events: Each of us will have a story to tell about this period. I hope our stories will all have happy endings. CW

ABOUT THE AUTHOR

Dale Brosius is the chief commercialization officer for the Institute for Advanced Composites Manufacturing Innovation (IACMI), a DOE-sponsored public-private partnership targeting high-volume applications of composites in energy-related industries including vehicles and wind. He is also head of his own consulting company, which serves clients in the global composites industry. His career has included positions at US-based firms Dow Chemical Co. (Midland, MI), Fiberite (Tempe, AZ) and successor Cytec Industries Inc. (Woodland Park, NJ), and Bankstown Airport, NSW, Australia-based Quickstep Holdings. He served as chair of the Society of Plastics Engineers Composites and Thermoset Divisions. Brosius has a BS in chemical engineering from Texas A&M University and an MBA.

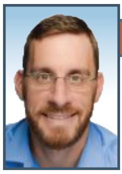
Composites Index contracts as COVID-19 disrupts economy

March 2020 – 38.4

» The Composites Index fell sharply in March to an all-time low of 38.4 as new orders, production, employment and exports all set historic low activity readings. Data from the second half of 2019 pointed to weakening business activity; then, towards the end of the first quarter, the world economy began to shut down due to efforts to contain the spread of COVID-19, disrupting supply chains and causing business confidence to sag. It is important to remember that these low index readings represent a decreased level of business activity in March as reported by manufacturers, and are not to be confused with actual rate of decline taking place.

Unlike the other Index components, the March reading for supplier deliveries activity moved significantly higher. In normal times, when demand for upstream goods is high, supply chains cannot keep pace with these orders, and the resulting backlog of supplier orders lengthens delivery times. This delay causes our surveyed firms to report slowing deliveries, and by our survey's design, elevates the supplier deliveries reading. Globally disrupted supply chains, as opposed to strong demand for upstream products, have lengthened supplier delivery times and caused the reading to increase.

The Composites Index is unique in its ability to measure the status of the composites industry on a monthly basis. For this reason, it is one of the industry's best tools for making data-driven decisions at a time when it is otherwise tempting to make impulsive and emotional decisions. Your participation in the survey enables Gardner Intelligence to accurately report to you, our readers, the impact of COVID-19 on the industry including the virus' eventual passing and resumption of more normal business conditions. With your help, it is our belief that the Composites Index will provide a first glimpse at that eventual and inevitable rebound. CW



ABOUT THE AUTHOR

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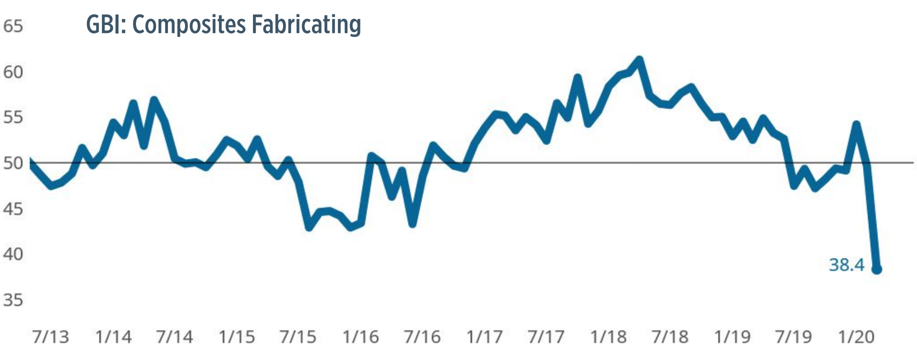
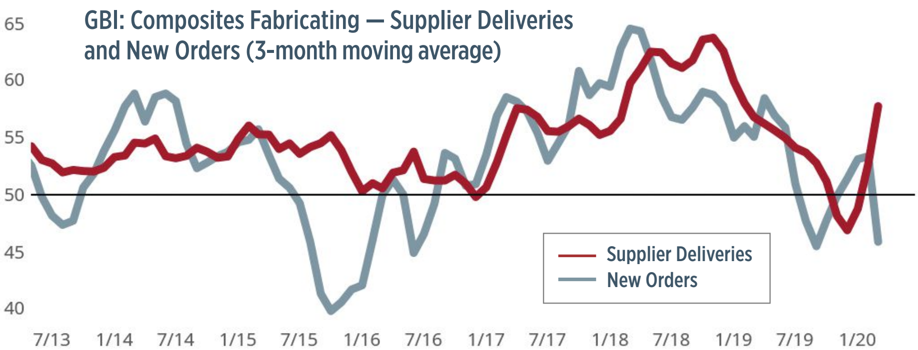


Record low reading

The Index was hit hard in March by the forced closure of much of the world's economy in order to slow the spread of COVID-19. Activity readings for new orders, exports, production and employment all set record low readings.



Fabricators report lengthening supplier deliveries while new orders fall to all-time low

Survey respondents reported a steep contraction among most elements of business activity. The reading for supplier deliveries is designed to increase when supplier deliveries slow, under the assumption that suppliers are experiencing higher backlogs and need longer to get parts to manufacturers. In the current situation, it is COVID-19's massive disruption to the world's supply chains that is causing longer delivery times.

TRENDS

This month's composites industry trends include stories of composites suppliers and fabricators stepping up to help fight the coronavirus pandemic, how one manufacturer is using Bluetooth and artificial intelligence to revolutionize its operations, and more.

Composites industry suppliers, fabricators help fight global pandemic

Over the past several months, various members of the composites industry supply chain have stepped up to help healthcare workers fight the coronavirus pandemic around the world. Some companies, like Eastman Machine (Buffalo, N.Y., U.S.), a global manufacturer of cutting tables used to cut glass and carbon fiber fabrics, have seen customers turn to them for solutions on how to retrofit current equipment for use with medical-grade materials that the companies began producing. Others have donated supplies, or altered their own production to produce needed medical or sanitation supplies. What follows are a few of the stories *CW* has gathered. For the latest coronavirus news, go to **compositesworld.com/covid-19.**


Source | Henkel

Disinfectants

Many chemical companies that produce resins, adhesives or other products for use in the composites industry have stepped in to produce disinfectants and hand sanitizers for use in hospitals around the world. In the U.K., Scott Bader (Northamptonshire, U.K.), which manufactures resins for composites fabrication, rapidly developed and brought to market a new thickener for alcohol-based hand cleansers. Similarly, INEOS (London, U.K.), which supplies unsaturated polyesters, vinyl esters and gelcoats to the composites industry, announced plans to step up its isopropyl alcohol and ethanol production to produce 1 million bottles of hand sanitizer per month to help with the shortage.

Source | INEOS

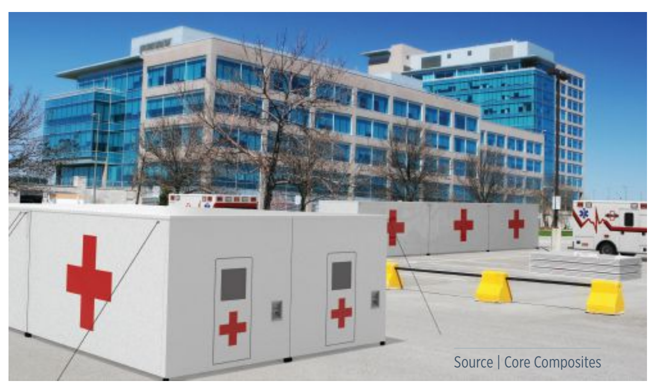
In France, chemical and resins supplier Arkema (Colombes, France) repurposed one of its production lines to manufacture 20 tons of alcohol-based solution per week to be distributed to hospitals in France. German supplier Henkel converted a production facility at its Düsseldorf site to produce 50,000 liters of disinfectant to donate to surrounding hospitals.

Ventilators

In March, a number of composites leaders, funded by the U.K. government, joined nationwide efforts to ramp up ventilator production for U.K. hospitals. Participants from the composites industry include Meggitt (Christchurch, U.K.), GKN (Redditch, U.K.), Renishaw (Wotton-Under-Edge, U.K.), Williams Advanced Engineering (Grove, U.K.), Bindatex (Bolton, U.K.) and many more. Project targets included production of up to 30,000 new ventilators for use by hospitals.

Shelters

Core Composites (Bristol, R.I., U.S.) has used its experience designing composite, rigid-walled shelters for the armed forces to develop an easily deployable shelter designed for use as temporary hospital space to aid the containment of COVID-19. The company partnered with defense contractor ADS Inc. to help sell and distribute the shelter.


Source | Core Composites

Face masks and shields

Many companies have also produced prototypes and production versions of face masks, shields and visors. For example, Composite Integration (Saltash, U.K.), in collaboration with several colleagues from across the U.K., has stepped up its production capabilities to accelerate the design of face visors for hospital use. Solvay (Brussels, Belgium) partnered with Boeing (Chicago, Ill., U.S.) to supply high-performance, medical-grade thermoplastic film to Boeing for its production of face shields for hospital use.

Carbon fiber composite components manufacturer Composites Resources (Rock Hill, S.C., U.S.) and its sister company CAT Resources have shifted to manufacture face masks and other medical supplies to meet healthcare shortages related to the coronavirus crisis.

AEROSPACE

Kanfit managing growth using Composites 4.0 systems


Source all images | Kanfit Ltd.

Kanfit Ltd. (Nof-Hagalil, Israel) is a high-growth, diversified composites manufacturer and aerospace tier supplier that uses Bluetooth sensors and an artificial intelligence (AI)-based system to optimize its operations. The system Kanfit installed was supplied by a Tel-Aviv startup, Trekeye, comprising Bluetooth (wireless) tags that are attached to each part's traveler, meaning the work order that travels with the part.

When the work order for a part is printed, the tag is attached to it and then delivered for production. For composite parts, the next steps could include automated cutting and kitting of prepregs or dry reinforcements, layup, preforming/debulking, resin transfer molding (RTM) or vacuum bagging and autoclave cure, trimming, nondestructive testing (NDT) and painting. Typically, there are multiple inspections in between these steps. The process chain could also include assembly with small and large metal parts into larger modules. Producing such modules, including installing various systems (e.g., wiring, insulation, distributed power, etc.) is a growing trend for aerospace tier suppliers. Once the process chain is complete and the part/assembly is ready to ship, the Bluetooth tag is removed and reused on a new work order.

Shachar Fine, EVP of business development, marketing and sales at Kanfit Ltd., explains that these are tags, not sensors. "A tag doesn't sense but just transmits a signal," he notes. In this case, each of the Bluetooth tags transmits its serial number every 10 seconds. "Antennas receive these signals and triangulate the position *(continued on page 12)*

(continued from page 11)

of each tag," says Fine. The final system component is the software, which collects the data, applies algorithms to analyze it and responds with alarms and/or suggested actions. The Bluetooth tags are battery powered, but the software alerts when the batteries are low on charge, and the batteries last for more than a year.

Kanfit explored using RFID tags, but because they use radio frequency (electromagnetic fields) to transmit data, metal interferes with the signal. "We have a lot of metal in our production environment," Fine explains. "So, you have to think of where to put the RFID antennas in the building so that each tag's signal is always received. If the RFID tags periodically don't register, then the entire data stream is compromised. With our Bluetooth tags, we proved 100% registration. We threw them in with metal parts and put them near different antennas. Every time, the system picked up 100% of the tags."

Another difference, he explains, is that the Bluetooth tags are active, sending out a signal, while RFID tags are typically passive — their signals only get picked up if they pass by an appropriately situated antenna. "With the Bluetooth tags, you position antennas where you want the system to report parts," says Fine. "So there is no technological restraint like with the RFID system. You can put the antennas on a wall, ceiling or a work station. Where you place them and how many you use in an area is a matter of what resolution you need. For example, in a waiting area, one antenna on the ceiling is sufficient, but in an area with several process steps, you may need multiple antennas."

One disadvantage of the Bluetooth system Kanfit installed from Trekeye is cost. "There is a lot of infrastructure," says Fine, "and these Bluetooth tags cost dollars, not cents like RFID tags." There was also significant development, requiring Trekeye developers to be onsite. "They helped us to locate the antennas so that the information we collected was optimized for what we were trying to achieve," he explains. "They taught us how to address issues with overlapping areas of antennas so that the system is not confused by one tag being read by two antennas at the same intensity. It was a process."

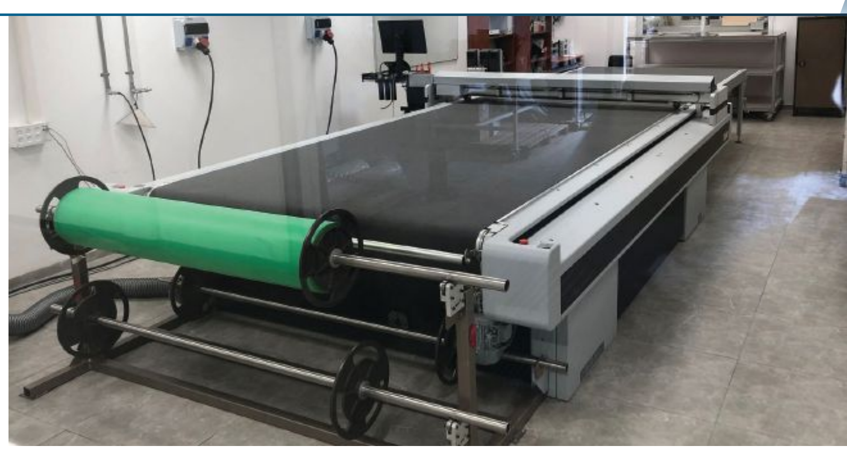
Once the system was installed and running, the results it returned included part maps and spaghetti charts. "Our IT department had the online map open for the system all the time," Fine explains. "When a worker was looking for a part, they went to IT, quickly located the part and then went to retrieve it in the plant. It was very easy to see where all of the parts were."

He explains that Kanfit has thousands of parts all over the production floor (3,000 open work orders every minute), "and it's not a standardized assembly line. The mix of parts being made changes and some parts require different steps than others. For example, not every part gets autoclaved or machined. When you see a part, you don't always know if it's in the right place. You need to check the part's paperwork to understand that."

The Trekeye system, however, worked amazingly well. "Even though it was not a cheap system, the ROI [return on investment] was very short," says Fine. "The system has a very advanced AI. It didn't wait until a part was missing. It would send an SMS [text message] to the manager that "ABC" part went to the wrong station. There was no waiting. The system would alert when a part didn't follow its normal route."

These part routes or paths are

(continued on page 14)



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shown on what is called spaghetti charts. "These show the paths of the parts through our factory and process chains," says Fine. "We were starting to see trends. For example, as engineers created the work orders for parts, they would put in inspection steps according to their knowledge and experience. Parts would go first to inspection before moving to the next station. The spaghetti charts would show that you could change some actions and reduce the distance that parts were traveling. We would see a part going back and forth between departments for multiple actions. We'd then sit with engineering and ask why is it going back and forth? How could we reduce four times down to two times, for example? This is easy to see in the chart but hard to see in actual day-to-day operations on the floor, and also what the actual effect of that back and forth is on overall production. You can see the steps as line items as you write them in the work order but to see the paths in the spaghetti chart is more data and a visualization of that data that has real impact."

"This also helped us as we have moved into our new, larger facility," Fine adds. "One of the lessons we learned is to centrally locate the inspection department within the production area. So, over time, I am sure the AI would continue to help us to better locate machines and stations, and even as our parts and operations change over time. It can also track tools."

Another benefit is that Kanfit could track how much time a part spends at each station. "Though we haven't yet implemented this, it could reduce the time employees spend entering such data," Fine notes. "We still have an ERP system that the employees report into, but the Bluetooth tag system gave better detail of when a part entered and left a station, etc."

Fine notes that these part and tool monitoring systems don't replace the ERP, but must be integrated to work with it. "We keep developing our ERP system in-house because we have big customers and every one of them has their own requirements. So, we have to develop a lot into our system in order to provide all of the information that each customer wants." But he sees the power of the Bluetooth tag/AI technology to improve these systems, and the advantage in further efficiency that offers.

Did Kanfit have to enter a lot of data for each part when it created the work order and attached the sensor? "No, that's the most amazing part," says Fine. "There was no data entry. It's the AI system. All it received was the work order numbers. These comprise letters and numbers, but there is a kind of logic to the way we come up with these and what they mean. The AI must have learned this. Once it started to gather data, it learned where the parts should be. For example, all "ABC" work orders were metal only and never meant to go to the composites department. So, when a metal part went to the composites department by mistake, the system alarmed. Even the AI designers were surprised at how quickly the system learned. We initially tested 100 parts. It learned within this first batch."

Fine explains that this is what the system was designed to do. Trekeye started in hospitals, working with a mobile medical device maintenance company that helped maintain blood pressure cuffs, thermometers, monitors, etc. That company complained that they were spending 80% of the maintenance technician's time just looking for the devices that needed maintenance. "With this system in place, the technician would come in, connect to the system and see exactly where all of the devices were in the hospital," says Fine. "An added benefit was that theft went down. Whenever someone would walk out with a device, the system would alarm and a security officer would be sent down to retrieve the device."

Unfortunately, Trekeye did not make it through the critical "Valley of Death" stage as a startup, and is no longer operating. "We have everything we need to keep the system running except for someone to oversee it," says Fine. "For this kind of system, you can't just have a general IT person. You need someone very proficient in AI. We are also just finished moving into our new facility and haven't re-initiated the system yet." He has searched for another company doing something similar but says he hasn't found anything that meets Kanfit's needs yet. "We will find a way to get it back into operation again soon," he adds.

So, what is the real benefit? "First, whatever you can't measure, you can't manage," says Fine. "Second, the amount of data we have is so huge, even for us as a small factory, that we're past the point of having one or more persons to be able to deal with all of this data. I can't even imagine what this must be like for Boeing or Airbus. We have to have the machines talk to each other now. Let them do what they're good at and let us humans look at the big picture and develop new solutions based on what they can show us."

Go to short.compositesworld.com/Kanfit_AI to see the full version of this story.

AUTOMOTIVE

Toyota and Hino to develop heavy-duty fuel cell truck using composite storage tanks

Source | Toyota Motor Corp.

Toyota Motor Corp. (Toyota City, Japan) and Hino Motors Ltd. (Hino, Japan) have agreed to jointly develop a heavy-duty fuel cell truck, and to proceed with initiatives toward its practical use including verification tests.

The heavy-duty fuel cell truck in this joint development project is based on the Hino *Profia* and will take maximum advantage of the technologies that Toyota and Hino have developed. The chassis is designed with optimum packaging for a fuel cell vehicle, and steps are being taken through comprehensive weight reduction to ensure a sufficient load capacity. The powertrain comprises two Toyota fuel cell stacks newly developed by Toyota and combined with vehicle driving control that applies heavy-duty hybrid vehicle technologies developed by Hino. Cruising range will be roughly 600 kilometers to meet high standards in both environmental performance and practicality as a commercial vehicle.

The Class 8 trucks Toyota is developing in the U.S.-based Portal Project also use two Toyota fuel cells as well as four 700 bar (70 MPa) Type IV hydrogen storage tanks made using composites to power a Kenworth T660 truck. The composite tanks were developed and manufactured by Hexagon Composites ASA (Alesund, Norway) and its subsidiary Agility Fuel Solutions (Costa Mesa, Calif., U.S.). Five of the 10 trucks planned in this project have been built and are in testing.

Toyota and Hino have declared goals to reduce CO_2 emissions by 2050 — 90% reduction from new vehicles compared to Toyota's 2010 levels and Hino's 2013 levels. To achieve these reductions, major improvements will be required in the environmental performance of heavy-duty trucks, which account for about 60% of the total CO_2 emissions from commercial vehicles in Japan.

For the electrification of commercial vehicles, an optimum powertrain must be adopted to ensure both outstanding environmental performance and practicality. Heavy-duty trucks are typically used for highway transportation; therefore, they are required to have sufficient cruising range and load capacity as well as fast refueling capability.

Toyota and Hino have positioned hydrogen as an important energy source for the future and have worked together on developing technologies and innovating fuel cell vehicles for over 15 years since their joint demonstration trials of the fuel cell bus in 2003.

Teijin's Sereebo CFRTP adopted for 4K video cameras

Source | Teijin

Teijin Ltd. (Tokyo, Japan) says its Sereebo carbon fiber-reinforced thermoplastic (CFRTP) is the world's first CFRTP for mass production (including automotive applications with the CarbonPro pickup box featured on select GM truck models), and that it significantly reduces molding time to enhance production efficiency.

Most recently, the material has been selected for use in two Panasonic Corp. (Kadoma, Japan) digital 4K video cameras, the HC-X2000 and HC-X1500, which were launched earlier this year.

A version of Sereebo developed for injection molding, which uses Teijin's polycarbonate resin Panlite as the matrix, has been adopted for the handle unit and top cover of both cameras.

The HC-X2000 and HC-X1500 video cameras both offer 4K60p/10-bit videography for professional applications including television broadcasting. The HC-X2000, which is about 40% smaller and 15% lighter than conventional models, is designed to combine mobility with a robust 4 hours and 35 minutes of continuous shooting.

Camera chassis and bodies are typically made with plastics reinforced with chopped carbon fibers for strength and reduced weight; however, Teijin says these short fibers cannot fully realize the strength and other features of longer carbon fibers. Sereebo is said to feature added strength, weight reduction and flame retardance as well as a smooth surface and the elimination of carbon fiber bosses (protrusions) on the surface.

Teijin says it is accelerating its development of mass-production applications for Sereebo, including precision equipment and consumer electronics that require both strength and reduced weight.

Tepex reinforces child seat headrest demonstrator

Tepex continuous-fiber-reinforced thermoplastic composite materials from LANXESS (Pittsburgh, Pa., U.S.) have shown potential for a variety of automotive applications — including support for a hybrid metal-composite automotive A-pillar, an automotive rear seat shell and a center console armrest demonstrator. A recent case study from the company adds lightweight construction of structural safety components to the list.

LANXESS recently developed a child seat headrest as a technology demonstrator to illustrate the materials' opportunities in this market. The component is produced in a particle-foam composite injection molding (PCIM) process. Tepex is developed and produced by LANXESS subsidiary Bond-Laminates GmbH (Brilon, Germany).

"The insert made of Tepex can reduce the weight of the headrest by up to 30% in comparison with the commercially produced component variant — and with comparably good crash performance, too. It also simplifies the production process," says Dr. Klaus Vonberg, of the Tepex Automotive Group at LANXESS.

Source, all images | LANXESS

The demonstrator is the result of a transnational research project funded by the German Federal Ministry for Economic Affairs and Energy as part of the Central Innovation Programme for Small and Medium-Sized Enterprises (SMEs) (German acronym: ZIM). Participating in this program are the Department of Lightweight Structures and Polymer Technology (SLK) at Chemnitz University of Technology, Polycomb GmbH (Auengrund, Germany) and child seat manufacturer Avionaut (Szarlejka, Poland).

For the headrest, the project partners developed an alternative production process based on PCIM. To reinforce the headrest in individual places and reduce weight, they used a customized insert made of Tepex dynalite 104-FG290(4)/47%, a polypropylene-based composite material that is strengthened with two layers of continuous glass fiber rovings.

The insert is formed in a single process operation using an injection molding tool with turning plate and back-injected with a short glass fiber-reinforced polypropylene compound to integrate the support structure for the headrest and backrest. The prefabricated insert is then back-foamed in a second tool using particle foam based on expanded polypropylene (EPP).

The reference headrest, by contrast, is currently produced in series using multiple individual components, according to LANXESS. The support structure consists of long glass fiber-reinforced polypropylene. It is assembled with a separately foamed EPP component using four polypropylene carrier pins.

The weight saving with the current version of the headrest component featuring glass fiber is roughly 26%, although project participants note potential for more if carbon fiber is used as the reinforcement material.

LANXESS sees potential for Tepex and the new process in the production of infant carriers, backrests and armrests as well as seat shells for new, highly complex seating concepts in autonomous cars or for comfort seats for shuttle, VIP and family buses and electric vehicles.

Curved pultrusions enter production

2020 *Corvette* CFRP rear bumper beam is the automotive industry's first use of new technology.

By Peggy Malnati / Contributing Writer

An industry first

Among its many notable innovations, the new 2020 Chevrolet *Corvette* sports car from General Motors Co. features the world's first radius pultruded auto part. The vehicle's rear bumper beam (shown here mounted to a rolling-chassis cutaway) was produced by Tier 1 supplier Shape Corp. using an innovative process and machine developed by Thomas GmbH + Co. Technik + Innovation KG that can produce curved pultruded parts. The carbon fiber composite beam uses a variety of noncrimp fabrics produced by Vectorply Corp. and infused with polyurethane-acrylate resin from Scott Bader North America.

Source | SPE Automotive Div.

» Among the most innovative composite parts on the eighth-generation, 2020 Chevrolet *Corvette* sports car from General Motors Co. (GM, Detroit, Mich., U.S.) is a curved, pultruded rear bumper beam. The design team desired a beam with curved geometry that better matched rear vehicle styling and fit in the available package space, which wasn't generous. The manufacturing team wanted the beam assembled to the rest of the body-in-white (BIW) in the "body shop," meaning it had to have thermo-mechanical stability to survive the 238°C bake cycle after a dip in GM's ELPO electrophoretic rust-coating bath. The beam also had to meet required low-speed impact crash requirements, and engineers wanted to reduce mass versus the metal-inert gas (MIG)-welded aluminum extrusion used on the previous-generation *Corvette*. Given that vehicle's history as a composites-intensive car, a composite beam was a logical starting point.

10 things in CFRP

As design work for the 2020 model got underway, the *Corvette* team picked 10 structural parts, including the traditionally aluminum bumper beams, that could be evaluated for potential production as new, fully carbon fiber-reinforced plastic (CFRP) parts.

"The parts we were looking at — some were straight, some were curved, some needed holes cut into them for one reason or another, but each one had to meet our dollars-per-kilogram target to be seriously considered," explains Ed Moss, *Corvette* body structure engineering group manager. "Out of the 10 parts we initially considered, five moved to the next level of evaluation, although three eventually were dropped later in development. We ended up with two [new] CFRP parts on the 2020 *Corvette*: the rear bumper beam and a removable underbody close-out panel for the center structural tunnel."

The design team initially considered use of carbon fiber composites for the vehicle's straight front bumper. However, for many reasons, chief among them the more stringent requirements to pass both low- and high-speed frontal barrier tests, the focus soon shifted to the curved rear beam, which had less demanding performance requirements and needed to lose more weight to accommodate the vehicle's new mid-engine design.

"Given that we thought we might be using new technology, and the front barrier tests have so many nuances, we decided to start with the rear beam instead," continues Moss. "The rear beam, which frames the rear of the car, is actually more important, given the mid-engine architecture, and we were willing to pay more to get more mass out of that end of the vehicle." A curved beam was needed both to match rear styling and to maximize rear luggage space. Given its proximity to mid-engine heat, the material needed thermo-mechanical stability, ruling out thermoplastics. The beam also needed to accommodate a coated aluminum tow hook, which would either need to be molded in or bonded in after cutting a hole post-molding.

Design work on the rear beam began in earnest even before material and process were selected. One aspect of the design that remained a constant throughout the program was the decision to bisect the hollow beam (along the length direction) via a central web, essentially creating two interior chambers. This feature was critical to keeping beam thickness and weight low while providing required mechanical performance for crash testing. As would be expected, the central web's presence affected process selection.

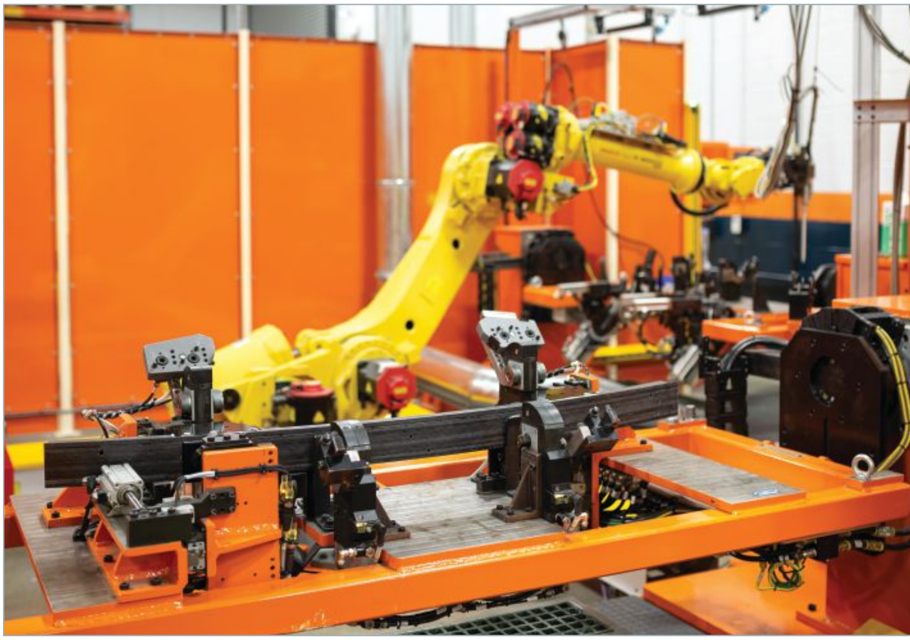
As the team considered how to produce first the straight front and later the curved rear bumper beam, they evaluated several composite forming processes judged capable of producing a two-chamber hollow beam. Among these were:

- Filament winding: ruled out as too slow and costly to meet target build volumes given the beam's dual-chamber design;
- High-pressure reaction injection molding: eliminated because it couldn't produce hollow beams with swept surfaces;
- Liquid composite molding: technically challenging owing to the central web, which would have required both a preform cavity and two mandrels, plus a method of creating backpressure to achieve the two-chamber design; and
- Pultrusion: a straight beam posed no problems, but only one process variant could reliably produce curved profiles in thermoset composites.

Interestingly, one team member had a process preference from the beginning. »

The first radius pultrusion line in the Americas

Shape Corp. is the first company in the Americas to own a radius pultrusion line developed and built by Thomas GmbH + Co. Technik + Innovation KG (TTI), and the first automotive supplier to produce commercial parts using TTI's patented process, which overcomes many of the traditional limitations of conventional (linear) pultrusion. Source | Shape Corp.



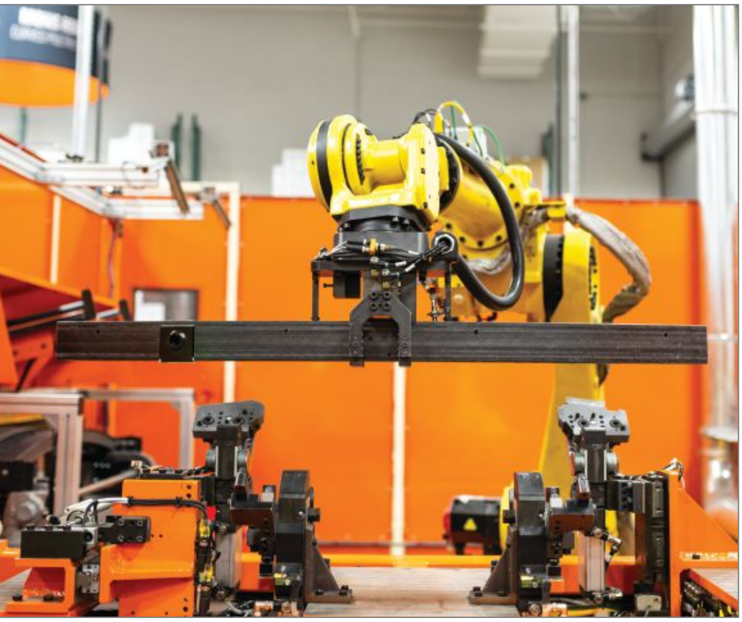
Installing an aluminum tow hook

An important post-mold assembly step performed at Shape is installation of the aluminum tow hook. Once a hole is drilled and the hardware is inserted, the tow hook is bonded into the waiting beam.

Source | Shape Corp.

Shape's multilayer barrier solution

Fasteners and brackets that will support the completed bumper's crash cans are installed on the beam. Shape uses a multilayer barrier solution — comprising strategically placed materials and coatings — to ensure the beam's carbon fiber reinforcement doesn't contribute to galvanic corrosion, while also minimizing mass and cost. Source | Shape Corp.



Transferring the beam for inspection

Following installation of bracketry, the six-axis robot transports the finished carbon fiber composite bumper beam to a final quality inspection station prior to shipment to GM's Bowling Green, Ky., U.S., assembly plant.

Source | Shape Corp.

"I'd wanted to use pultrusion on the *Corvette* for at least two models, but hadn't found the right application," recalls Chris Basela, Corvette body structure lead engineer. Basela had worked with Tier 1 supplier Shape Corp. (Grand Haven, Mich., U.S.) on previous *Corvettes* and other programs, and was impressed with the company's ability to produce complex, curved bumper beams in aluminum alloys and advanced high-strength steel. Shape designs, engineers and produces metallic, plastic and composite products, and is known for its expertise in energy management. The company already had pioneered several metallic bumper-beam technologies that improved performance at lower weight.

In turn, representatives from Shape had met with German machinery OEM Thomas GmbH + Co. Technik + Innovation KG (TTI, Bremervörde, Germany; see Learn More), which had invented a process and machine to produce curved 2D and 3D profiles via pultrusion. Shape was already in discussions with TTI to purchase a machine and license the technology when the *Corvette* opportunity presented itself.

Design and characterization

As Shape waited for its new radius pultrusion machine to be built, GM, Shape and engineered fabrics supplier Vectorply Corp. (Phenix City, Ala., U.S.) began evaluating and characterizing various fiber/resin combinations (see Learn More). For each candidate, the team modeled performance via finite element analysis (FEA) using GM's beam design, then molded test plaques using Shape's vacuum infusion system at its Grand Haven lab. Next, specimens were cut and small-scale tests were run to correlate predictions against measured results, helping the team gain confidence with its engineering assumptions. Additional plaques of the most promising candidates were molded and sent through the ELPO line at GM's Bowling Green, Ky., U.S. plant, where *Corvettes* are assembled.

Extensive investigations of fabric architecture helped the team understand what would and would not work in pultrusion — particularly radius pultrusion. Numerous fabrics were studied, including weaves and noncrimp fabrics (NCF) in fiberglass, carbon fiber and carbon fiber/glass fiber combinations.

"We liked the performance NCFs gave us because — since they're stitched — fibers don't shift during processing, which means higher stiffness and strength at the same areal weight, better drapeability, plus higher FVFs [fiber-volume fractions] in the final part," Basela explains. "We decided to fine-tune our performance with unidirectional tows."

"While we liked the cost of all-glass fabrics, going that route created a heavier beam to meet performance objectives, so we ended up with all carbon," Moss adds. Final fabric selection included a double bias, a warp triaxial and two warp unidirectional NCFs, most in small tows, and all in standard modulus with glass veils. Final FVFs averaged in the mid-50% range.

Additionally, the team evaluated many polyurethane (PUR) resins to find a candidate ductile enough to pass crash testing, thermally stable enough to survive ELPO and chemically compatible with structural adhesives used to bond the beam to the BIW.

Spanner in the works

Next, near-full-size beams were produced on TTI's demonstrator line in Germany for crash testing and the ELPO line. Things were going as expected until beams went through ELPO in Bowling Green, which is when issues were discovered.

"We started seeing blisters on almost every beam we sent through the line," Basela recalls. "They weren't just aesthetic problems that could be refinished; the blisters were pushing fibers out of the way and causing delamination issues. Oddly enough, the issue wasn't confined to one or two areas, but rather, blisters could show up in almost any location on any beam." This issue led to an intensive second study of alternative resin systems from several suppliers. More PUR resins were evaluated, as was epoxy, vinyl ester and some hybrid systems. Again, candidate materials were modeled, molded and tested; promising candidates were scaled up to near-full-size beams to be sent for more crash and ELPO testing.

LEARN MORE

Read this article online | short.compositesworld.com/Corvette20

Read more about pultruded auto parts | short.compositesworld.com/auto_pultr

Read more about the NCFs and resins used | short.compositesworld.com/Corvresins

The resin eventually selected had not shown outstanding performance in preliminary tests, but it aced ELPO. Crestapol 1250 is an off-the-shelf, peroxide-cured polyurethane-acrylate copolymer developed by resin supplier Scott Bader Co. Ltd. (Wellingborough, U.K.) as an adhesive and later modified to become a molding resin (see Learn More). The total system of resin/reinforcement offered the best balance of crash performance, ELPO survivability and mass/cost reduction with acceptable processing times.

Many firsts

This bumper beam is the world's first radius pultruded automotive part and the first radius pultruded part produced in North America in any industry. The profile is produced using a combination of bobbins and spools of materials. Production speed is said to be comparable with linear pultrusion — roughly 31 centimeters per minute. To date, GM has filed one and Shape four patents for innovations on the application. The final beam is 2.2 kilograms lighter than the previous aluminum extrusions, yet met all design, engineering and manufacturing targets. To date, the beam has earned two awards from the Society of Plastics Engineers (SPE, Danbury, Conn., U.S.): the Process/Assembly/Enabling Technologies category winner and the Vehicle Engineering Team Award (for the whole *Corvette* vehicle/team). CW

ABOUT THE AUTHOR

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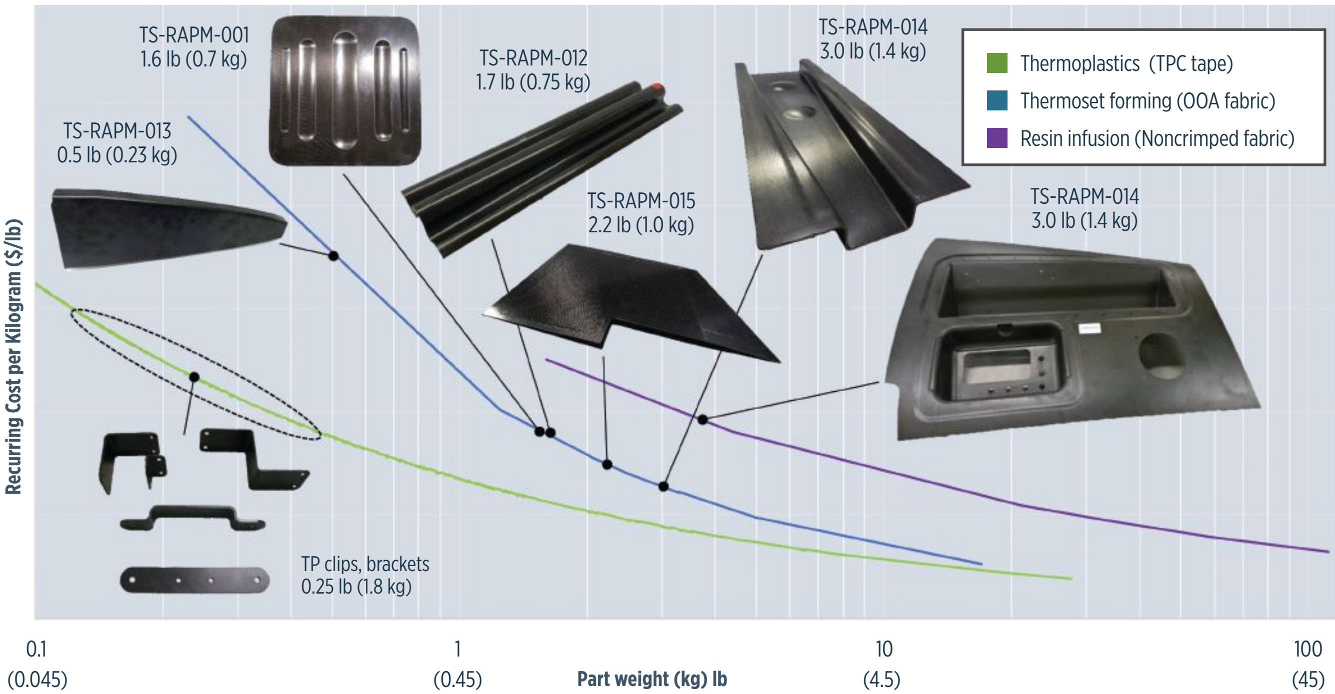


Revolutionizing the composites cost paradigm, Part 2: Forming

Boeing-led parts trials explore infusion, compression molding and thermoplastics, offering lessons and supply chain options to better compete with aluminum.

By Ginger Gardiner / Senior Editor

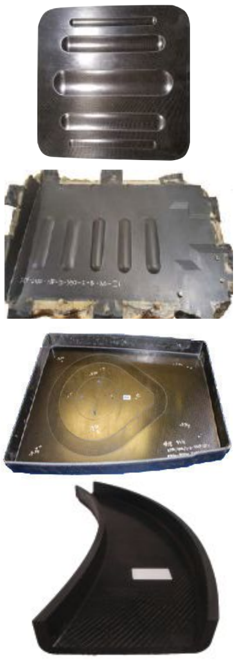
»The Tailorable Feedstock and Forming (TFF) program was launched by the Defense Advanced Research Projects Agency (DARPA, Arlington, Va., U.S.) in 2015 to enable rapid, low-cost and agile manufacturing of small, complex-shaped composite parts for defense aircraft. This 48-month program aimed to increase the cost-competitiveness of composites in order to exploit their weight savings and resistance to corrosion and cracking versus machined aluminum. In Part 1 of this series, *CW* explored TFF's vision and its Tailorable Universal Feedstock for Forming (TuFF) subprogram, which developed a short-fiber sheet material with high mechanical properties and metal-like formability (see Learn More).

In this article, the focus moves from feedstock to forming with TFF's second subprogram: RApid high-Performance Manufacturing (RAPM, pronounced "wrap-em") led by The Boeing Co. (Chicago, Ill., U.S.). The program began in July 2016 and has presented its results in numerous publications including six papers and two presentations at SAMPE 2019. RAPM's goal, as explained by Boeing technical fellows and principal investigators Gail Hahn and Tom Tsotsis, is to "revolutionize the cost paradigm for small composite parts, enabling pervasive use in defense applications."

"We started out with this vision of achieving aerospace

Recurring cost trends by component size

The RAPM subprogram within DARPA's Tailorable Feedstock and Forming (TFF) program compiled analytical data from current/past production as well as empirical data from its own forming trials for multiple parts to generate these curves. The goal is to better understand the trade space for composite parts and processes. Source for all images | The Boeing Co., DARPA



Pathfinder Parts	Resin Infusion		Thermoset Prepreg		Thermoplastic Forming	
	HP-RTM	Gap Infusion	Press-forming	Surface Generation PtFS	Press	Stamp-forming
Beaded panel (-001 or -009)	API DD3-84, Huntsman FAF2 **RI-RAPM-009**		T300-3K-70-PW/ CYCOM 970, T650/ CYCOM 5320-1, T650/ CYCOM EP2750 **TS-RAPM-001, -009**	T650/ CYCOM 5320-1, T650/ CYCOM EP2750 **TS-RAPM-001, -009**		
Rib (-002)	API DD3-84, Huntsman FAF2 **RI-RAPM-002**		T650/ CYCOM 5320-1, T650/ CYCOM EP2750 **TS-RAPM-002**		Solvay AS4D/ PEKK-FC (Accudyne Press) **TP-RAPM-002**	
Curved Channel (-003)	API DD3-84, Huntsman FAF2 **RI-RAPM-003**	Huntsman FAF2, CYCOM 823 **RI-RAPM-003**	T650/ CYCOM 5320-1, T650/ CYCOM EP2750 **TS-RAPM-003**		Consolidate preform (PtFS) **TP-RAPM-003** →	2x2 twill Solvay AS4D/PEEK-FC, 5HS Solvay AS4D/PEEK-FC **TP-RAPM-003**

Reinforcement for all RI-RAPM parts: SGL Sigratex C U170-0/ST UD fabric made with SGL Sigrafil T50-4.4/255E100 carbon fiber. **API DD3-84** is a two-part epoxy from Applied Poleramic Inc. (API), now acquired by Kaneka. **T650** is Solvay Thornel high-strength, standard modulus carbon fiber; **T300**-3K-70-PW is Toray standard modulus carbon fiber, 3K tow, plain weave (PW) fabric. The experimental **Solvay XEP-2750** is now commercially available as CYCOM EP-2750

FIG. 1 RAPM manufacturing development trials

Initial forming trials comprised three main process tracks and three main part configurations designed to develop design and process guidelines for subsequent challenge and transition parts (shown in Fig. 2. p. 26).

performance with automotive efficiency," says Hahn. The program worked with automotive composite materials and parts manufacturers, including Solvay Composite Materials (Alpharetta, Ga., U.S.) and SGL Composites (Ried and Ort im Innkreis, Austria), but achieving aerospace properties wasn't always straightforward. "Although lower-temperature, rapid-cure epoxies are readily available for automotive applications, they do not come close to meeting aerospace requirements," says Tsotsis. RAPM did use new, rapid-cure, two-part epoxies targeting aerospace-grade resin infusion parts. However, initially, the molding system at SGL could not exceed 130°C, which prevented reaching the goal of 30 minutes time on tool.

"Our goal was to achieve 30 minutes maximum time on tool to enable the use of a high-rate work cell to reduce system-level costs to be cost-competitive with machined aluminum," says Tsotsis. "Within Boeing we decided that would satisfy everything we were seeing for defense applications," adds Hahn. "Why set it here when we can get 2 to 6 minutes with thermoplastics? Because thermoplastics require even higher temperature processing with corresponding tooling constraints, and our goal is to give our supply chain plenty of options."

As the program moved forward, it opened up to aerospace materials and manufacturers and even experimental systems, such as Solvay's XEP-2750. "We originally thought we'd be able to fully evaluate this system, as we did with CYCOM 5320-1 in our work with the DARPA program 'Non-Autoclave Manufacturing Technology' from 2007 to 2012," says Hahn. Though the same degree of evaluation wasn't possible, XEP-2750 has now been commercialized by Solvay as CYCOM EP-2750 (see Learn More) and benefited from the numerous RAPM part trials and lessons learned.

"All I want is a couple of processes for small composite parts that can win against aluminum in a trade study," says composites industry and TFF program consultant Jeff Hendrix of his goals for RAPM. So, has RAPM succeeded? *CW* explores the program's efforts to manufacture hundreds of parts, comparing more than a dozen aerospace part configurations through multiple materials and processes, while pursuing methods to reduce time and cost.

Program framework

Working with key industry partners, RAPM trialed parts in three primary tracks:

- Resin infusion with HITCO Carbon Composites (Gardena, Calif., U.S.) and SGL Composites
- Thermoset prepreg forming with Solvay Composite Materials (Heanor, U.K. and Anaheim, Calif., U.S.), Fiber Dynamics (Wichita, Kan., U.S.) and Reinhold Industries (Santa Fe Springs, Calif., U.S.)
- Thermoplastic forming with ATC Manufacturing Inc. (Post Falls, Idaho, U.S.) and TxV Aero (Bristol, R.I., U.S.).

Forming trials were completed in two phases: an initial "Manufacturing Development" phase (Fig. 1) followed by subsequent "Challenge and Transition" (C&T) parts (Fig. 2, p. 26) to *challenge* initial developments and *transition* candidates with potential to win against machined aluminum.

Manufacturing development trials used three primary part configurations: beaded panels (there were two types), a rib with »

C&T Parts	Resin Infusion*	Thermoset Prepreg		Thermoplastic Forming	
	LP-RTM	Press-forming	Surface Generation PtFS	Surface Generation PtFS	Stamp-forming or Overmolding
Double-pan RTM Challenge RI-RAPM-004	SGL Sigratex UD/ FAF2 epoxy Two aero fabrics/ HexFlow RTM 6-2 or RTM 6				
Solvay Challenge TS-RAPM-007		T650/ CYCOM 5320-1, T650/ CYCOM EP2750			
Skin Access Panel TS-RAPM-008 TP-RAPM-008		T650/ CYCOM 5320-1, T650/ CYCOM EP2750		Chopped Solvay AS4D/PEKK-FC	TxV Aero Overmolding Victrex AS4/AE250 with Victrex 150CA30
Boeing "Wave" TS Challenge TS-RAPM-012			T650/ CYCOM 5320-1, T650/ CYCOM EP2750		
Rib TP-RAPM-013					ATC Stamp-forming Solvay AS4D/PEKK-FC
Motor Arm TS-RAPM-014		T650/ CYCOM 5320-1, T650/ CYCOM EP2750			
Fin TS-RAPM-015		T650/ CYCOM 5320-1, T650/ CYCOM EP2750			
Z-spar trade study RAPM-005					
Bladder Study Net Part Features TP-RAPM-017				Continuous Solvay AS4D/ PEKK-FC	

Reinforcement for all RI-RAPM parts: SGL Sigratex C U170-0/ST UD fabric made with SGL Sigrafil T50-4.4/255E100 carbon fiber.
Two aerospace fabrics used with HexFlow RTM6: 3K-70-PW AS4 (3K AS4 carbon fiber, 193 gsm plain weave fabric) and HTS 40 2x2 twill with nonwoven veil (high tensile strength carbon fiber fabric). **T650** is Solvay Thornel high-strength, standard modulus carbon fiber; **T300**-3K-70-PW is Toray standard modulus carbon fiber, 3K tow, plain weave (PW) fabric. **TxV Aero overmolded** AS4/ Victrex AE250 PAEK UD tape blanks with Victrex 30% discontinuous carbon fiber reinforced PEEK 150.

FIG. 2 RAPM challenge and transition trials

Selected parts from the initial phase were defined for one or more processes to *challenge* initial developments and transition candidates with potential to win against machined aluminum.

pad-ups (ply build-ups) and a curved C-channel. These incorporated features common to aerospace parts that can cause manufacturing challenges: the beaded panel had multiple out-of-plane features plus pad-ups, pad-downs and a vertical edge; the rib panel had a pad-up with multiple 90-degree edges as well as a joggle in one of the edges; and the C-channel had different inside and outside radii, varying curvature in the flanges and significant ply drops in the web.

The goal was to develop design and manufacturing guidelines for each of the three tracks. "It didn't look sexy doing these first trials," recalls Hahn. "But they helped determine acceptable radii and part geometries that would produce parts without unwanted fiber distortion as well as optimal combinations of parameters such as applied tension, temperature, pressure and time on tool."

All three RAPM material and process tracks included trials using a Surface Generation (Rutland, U.K.) Production to Functional Specification (PtFS) pixelated-heating control and tooling system (see Learn More), located at Boeing R&T in St. Louis, Mo., U.S. "This came about because we were looking for a work cell that could accommodate all three types of materials/processes in a flexible rate environment," says Hahn. "We were able to explore different temperature control approaches and costs." The Boeing PtFS cell has a maximum temperature of 440°C, a clamping force of 150 tons and an effective part volume of 750 by 750 by 100 millimeters.

Although the original vision was to use TuFF short-fiber sheet materials, because these were not available at the onset, RAPM proceeded with surrogate materials. This is actually beneficial for the composites industry because the surrogates span materials that are more reflective of what is being used and developed outside of this project: automotive organosheets and aerospace-qualified prepregs, experimental epoxies, semi-crystalline thermoplastics and chopped prepreg compounds. Thus, the results and findings relate to all types of composites manufacturers, not just to those in the defense industry.

Track 1: Resin infusion/RTM manufacturing

Manufacturing development trials in this track started with automotive-type materials and processes. Parts were made by SGL Composites using high-pressure resin transfer molding (HP-RTM,

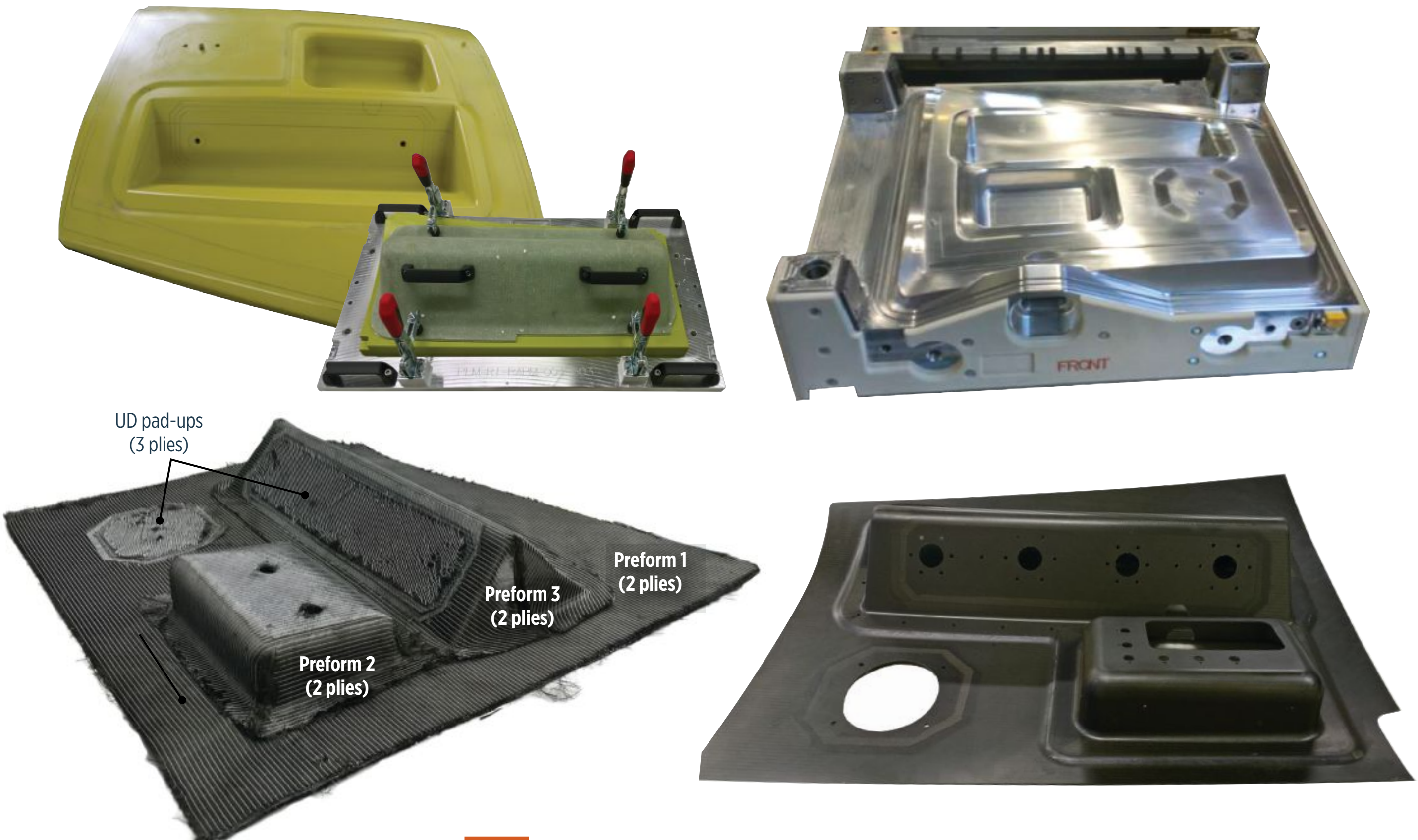


FIG. 3 Resin-infused challenge part

The RI-RAPM-004 deep-draw challenge part was made using low-pressure preforming and RTM, which permitted cost-effective Raku-Tool tools and hand-clamping mechanisms for preforming (top left) and aluminum tools for curing (top right). Multiple preforms were used to create the deep-draw geometry without wrinkles.

300 bar) and C T50 standard modulus, 50K carbon fiber noncrimp fabrics (SGL Carbon in Wackersdorf, Germany) in three part configurations: RI-RAPM-009, RI-RAPM-002, RI-RAPM-003 (Fig. 1, p. 25). These were used to identify preform parameters necessary for high-quality finished parts. Gap infusion (compression RTM, or C-RTM) was also trialed for RI-RAPM-003 by Boeing St. Louis using its PtFS system.

Computational flow modeling was used to better understand how to infuse these parts, analyzing process behavior to optimize materials and process parameters and to evaluate injection scenarios.

Tooling approaches were evaluated for how and when to apply tension to different types of preform geometries in order to minimize fiber distortion. These design changes were validated for a modified C-channel geometry, followed by computed tomography (CT) analyses. Lessons learned were applied in the subsequent C&T phase, moving to low-pressure RTM (LP-RTM) to reduce cost.

Within these pathfinder part trials, delaminations were found in several of the deep-draw radii. Tsotsis believes these were caused by a combination of insufficient initial cure of the resin in the tool — because SGL's steam heating system restricted in-tool temperatures to 130°C — and thermal/mechanical out-of-plane stresses during part removal. "Because the resin strength had not yet been sufficiently developed, these anomalies likely could have been eliminated with full cure on the tool, he suggests. "SGL could not meet both time on tool *and* aerospace properties until oil heating (versus steam only) was added to the tool, enabling cure above 130°C," notes Hahn. This was added after the manufacturing development trials.

Deep-draw challenge part

Results from the manufacturing development trials were then used to develop challenge and transition trials. Modeling was also completed for the RI-RAPM-004 deep-draw challenge part (Fig. 3), which features two deep draws: a 5-centimeter rectangular region and a 10-centimeter region that transitions from rectangular to a V-shape. Inspired by a production pan assembly, its complex geometry ensured a non-uniform resin flow path. Huntsman (Basel, Switzerland) performed the flow modeling with PAM RTM software (ESI Group, Paris, France) for an LP-RTM process using FAF2 two-part epoxy (Huntsman, The Woodlands, Tex., U.S.) and SGL Carbon NCF 150-grams per square meter biaxial and 190-grams per square meter unidirectional (UD) reinforcements.

RI-RAPM-004 comprises one preform for the skin, one for each of the deep-draw sections, plus two build-up areas (Fig. 3). »

Different layups were used for these preform elements to meet designed panel thicknesses (see Learn More).

Low-pressure preforming and LP-RTM allowed the use of cost-effective tools (compared to steel): the preform tool, with hand-actuated clamps, was made with polyurethane-based Raku-Tool material (RAMPF Tooling Solutions, Grafenberg, Germany); the curing tool was made with 5083 aluminum.

Initial RI-RAPM-004 trials showed an unexpected anomaly in the flow near the exit that lifted the surface plies, causing fiber distortion. Reversing the inlet and outlet resolved the issue. After infusion and initial cure in a 130°C tool, parts were post-cured at 180°C for 60 minutes and then machined to net shape. Ten high-quality parts were delivered to Boeing for automated ultrasonic system (AUSS) C-scans.

The finished challenge parts showed full consolidation, excellent fiber alignment and good quality. The parts exhibited a glass transition temperature of 197°C and had a fiber volume fraction (FVF) of 49.5%, typical for the NCF used. Part layup piece count was reduced by more than two-thirds versus the current prepreg process, and touch labor dropped by an estimated 90%. RAPM has also made the challenge part with aerospace-qualified resins and fabrics — to test the adaptability of the tools and processes it developed — and fabricated parts that passed production requirements for nondestructive testing (NDT).

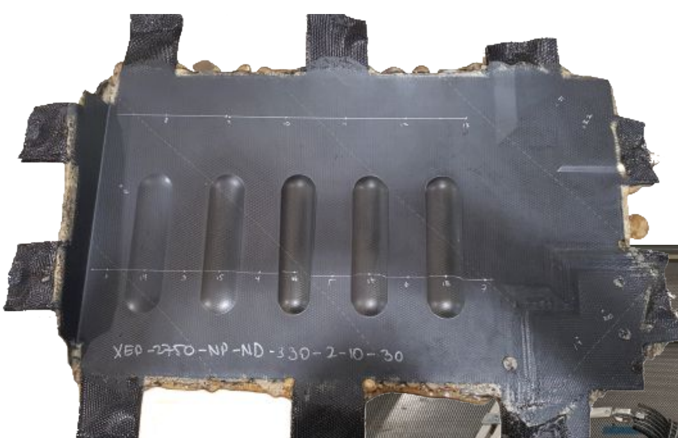
Track 2: TS prepreg forming

Three manufacturing development thermoset (TS) prepreg parts were manufactured at Solvay's Applications Center in Heanor, U.K., using spring-frame stamping and/or double-diaphragm forming (DDF). All three parts were manufactured using epoxy prepregs based on Solvay resins including CYCOM 5320-1, CYCOM 970 and the CYCOM EP-2750 aerospace system. "CYCOM 5320-1 is our go-to for out-of-autoclave (OOA) parts, but it's also used as a qualified system for the autoclave," says Hahn. "CYCOM 970 is a solvent versus hot-melt prepreg option, and [CYCOM] EP-2750 is our system for press forming because it is optimized for the physics and kinetics of the process, which we showed produces the best parts."

Spring-frame stamping and DDF are isothermal compression molding processes in which thermoset prepregs are cut, collated and consolidated into a 2D preform. The preform is then preheated, shuttled into matched metal tools and molded into shape in a conventional hydraulic platen press. The preform may be held in tension by a spring frame (Fig. 4), which reduces wrinkling induced by material compressive zones during forming. Alternatively, DDF sandwiches the preform between two diaphragms, eliminating the need for mold cleaning and release. The preform is taped to one of the diaphragms, essentially holding it in tension, though not as directly or tailorable as with a spring frame. In RAPM, spring type, locations and tensions were optimized for each part using simulation, as was the spring frame. For example, the beaded panel TS-RAPM-009 used a frame that can actuate up and down to tailor the forming of the charge in parallel with press closing.

RAPM minimized part-on-tool time by removing dimensionally stable parts after a 15-30-minute initial cure and then batch post-curing to increase rate capability. Part families were also investigated using a single toolset — e.g., a C-channel with three varying flange angles along the length of a wing — to maximize cell use. Other goals guiding the RAPM TS approach included:

- Automated collation and forming to minimize hand labor
- Aerospace mechanical performance with 177°C cure
- Steel tooling capable of more than 1,000 parts per toolset.



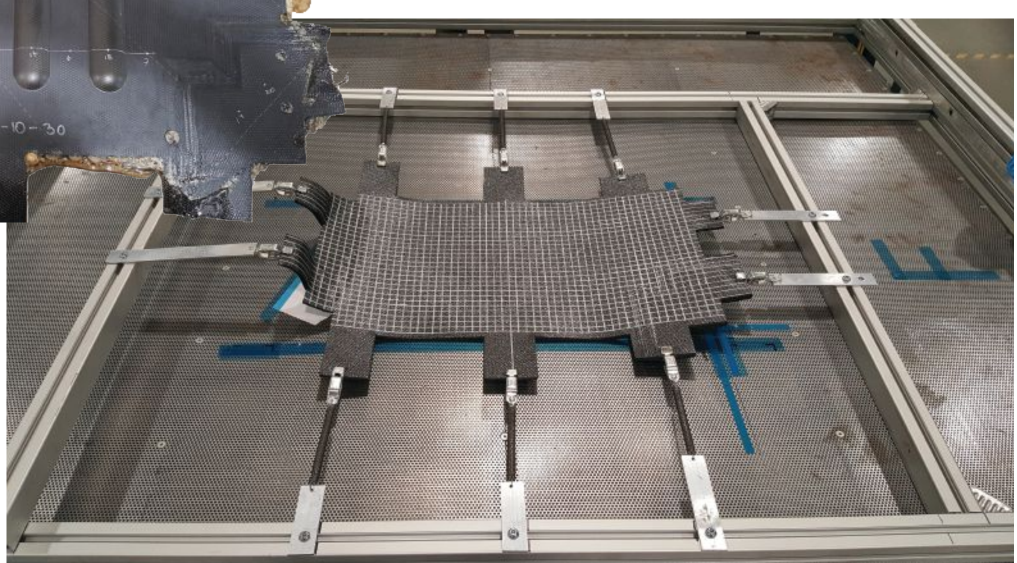


FIG. 4 Spring-frame compression molding

Spring-tensioned prepreg charge prior to compression molding (right) and molded part (left) for beaded panel TS-RAPM-009.

Development to "wave" challenge part

Thermoset prepreg manufacturing development parts were formed, indexing one variable at a time, until sufficient part quality was reached. Variables such as press closing speed, closing position and closing pressure were assessed, with the aim of consolidating the material at the correct point in the rheology curve to create internal hydrostatic pressure, minimize resin bleed and prevent cure from advancing too far, to avoid crack induction. Once forming parameters were set, three to five parts were made to verify process repeatability and then tested for quality. The beaded panels showed porosity of less than 0.5% due to high consolidation pressures (20.7 bar). Repeatable, high-quality ribs were also produced.

Lessons learned were then applied to the corrugated "wave" challenge part, TS-RAPM-012, to demonstrate compression molding of thick (6.3-millimeter nominal thickness) UD laminates in shapes with tight-radius (12.7 millimeters) curvature. To meet application requirements, the part used a quasi-isotropic layup of intermediate modulus (IM7; Hexcel; Stamford, Conn., U.S.) carbon fiber UD tape. Outer layers of style 108 glass fiber fabric and Solvay THORNEL T650 standard modulus carbon fiber in an 8-harness satin fabric protect the UD fibers and prevent galvanic corrosion on the side that mates to a metal part. Using Solvay CYCOM 5320-1 epoxy resin allowed shorter-length (greater than or equal to 30 minutes) isothermal cure cycles with a 2-hour freestanding post-cure at 177°C.

The wave challenge part was molded using Boeing's PtFS work cell and P20 steel mold faces with integrated vacuum and resin seals. The tool cavity was thinner than nominal laminate thickness to account for variation in the resin content of the material, maintaining internal hydrostatic pressure for high-quality parts.

Three process parameters were tested, including cold forming (pre-shaping plies without heat), hot debulk pre-consolidation and preheating the preform. Cold forming was rejected as time-consuming and not helpful. For pre-consolidation, laminates were vacuum bagged to a plate with a woven fiberglass breather and debulked under full vacuum in a 116°C oven for 40 minutes. Though an automated infrared preheat is standard for industrial production, in these trials, preheat comprised placing the preform in the hot mold (179°C) and closing as much as possible without touching for 3 minutes. The part was then compression molded.

Trial 8 of the nine completed (#0-8) produced the highest quality part, mainly attributed to pre-consolidation. Samples taken from it met thickness (an issue with other parts) and laminate quality with a fiber volume of 59-63% and void content of 0-0.6%.

Track 3: Bladder-formed TP rib and C-channel

RAPM chose the TP-RAPM-002 rib from the manufacturing development trials to demonstrate single-step compression molding from raw material to finished complex part, and the TP-RAPM-003 curved channel for a two-step approach. Boeing St. Louis molded the -002 rib using an Accudyne Systems (Newark, Del., U.S.) press and consolidated blanks for the -003 C-channel using the PtFS equipment. In a second step, ATC Manufacturing stamped the C-channel blanks into parts.

SIDE STORY

Thermoplastic (TP) forming issues

TP composites process at higher temperatures than thermosets — e.g., 390°C for PEEK and 375°C for PEKK — which presents a number of issues. Tooling materials that can handle these high process temperatures are limited. Further, the large temperature delta between part processing and removal makes it difficult to maintain uniform tool temperature. The remedy is heat soaks and/or slower ramps up and down, which lengthen cycle times.

The high temperatures also present a coefficient of thermal expansion (CTE) challenge. The tooling material's CTE is often different than that of the TP laminate, which can cause the TP laminate to shrink away from the tool, reducing the pressure applied and preventing full consolidation. Also, the TP laminate CTE is constant along the carbon fiber but a bi-lineal curve perpendicular to the fiber. This results in different shrinkage in-plane versus out-of-plane as the TP laminate heats and cools and should also be addressed in tooling design.

TP laminates may also shrink from tooling as resin volume decreases with the change from liquid to solid. It is during this cooling phase, when critical resin matrix crystallization occurs, that accurate control over temperature uniformity and laminate pressure is required to ensure high-quality properties in the finished part.

Another issue is that tools need to be fully sealed to contain the molten TP liquid during molding. "Sealing a tool at 375°C to 390°C is difficult as there are very few conformable gaskets that can handle this temperature and TP forming pressures of 300 to 500 psi or greater," says Hahn. "We are limited to either metallic gaskets or matched metal tooling to provide the sealing features. Elastomeric tooling would be incredibly beneficial, however all current elastomers will break down at TP forming temperatures."

For the -002 rib, RAPM used 12-inch-wide UD tape supplied by Solvay: 12K AS4D carbon fiber (Hexcel, Stamford, Conn., U.S.) reinforced polyetherketoneketone (PEKK). The -003 C-channel used fabric from Cramer Fabrics Inc. (Dover, N.H., U.S.): 3K AS4 (Hexcel) unsized carbon fiber in a 2x2 twill, powder-coated with polyetheretherketone (PEEK); fiber areal weight is 250 grams per square meter; resin content is 42%.

Boeing St. Louis required novel tooling to create horizontal pressure on the rib's vertical elements during consolidation in a hydraulic press that had only vertical actuation. Its solution was a thin aluminum bladder (a similar system was used to form TP-RAPM-003, Fig. 5, p. 30). Pressurized with inert argon gas at high temperatures, the bladder expanded to apply even pressure to all part surfaces during consolidation.

Top and bottom tools were made from 410 stainless steel, which matched the in-plane CTE of the UD carbon fiber/PEKK laminate. During the press cycle, the upper tool with the aluminum bladder came down and slowly pressed the layup into the female cavity of the lower tool. The bladder was undersized 30% from the final part thickness to accommodate the bulk of the unconsolidated tape preform in this one-step process. This tool was mounted in a conventional press with electric heating cartridges, wired in 12 independently controlled zones — plus the six main zones of the »

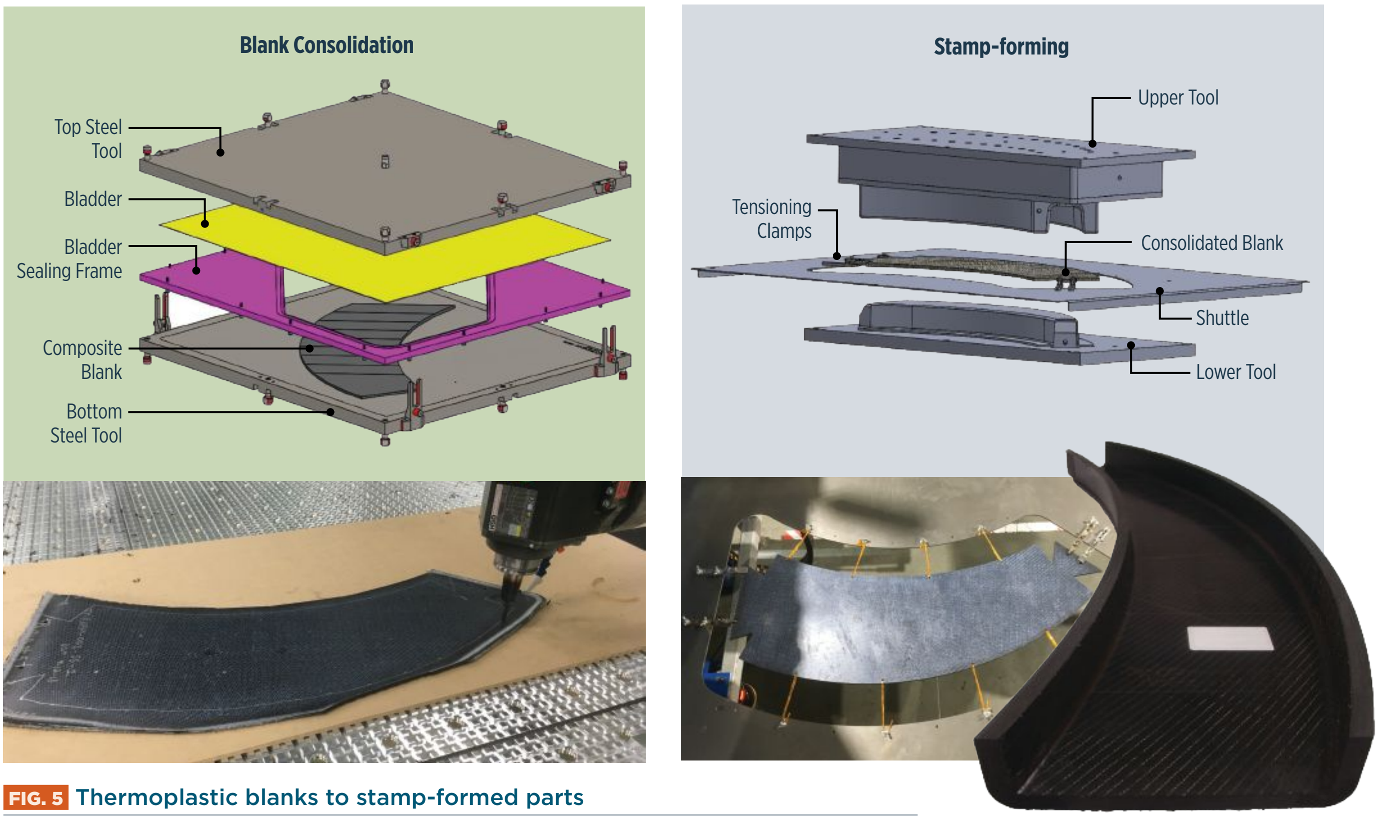


FIG. 5 Thermoplastic blanks to stamp-formed parts

Boeing consolidated the PEEK fabric blanks for the TP-RAPM-003 curved C-channel using an aluminum bladder and its PtFS system. Consolidated blanks were then sent to ATC Manufacturing, where they were stamped while held in a tensioning system to prevent wrinkles.

press platen — to control the tool surface temperature in the rib's flanges and web.

These forming trials produced composite parts with passable NDI results. However, the bladder tool design requires further development to improve forming the layup into the tight inner radii of the part and also to maintain uniform surface thickness.

Consolidating PEEK fabric blanks

For the TP-RAPM-003 curved C-channel, the powder-coated PEEK 2x2 twill fabric used had a relatively high bulk factor. Boeing St. Louis first consolidated the layup, which dropped from 32 to 24 plies along the length of the part, into a flat blank with a tapered cross-section, and then sent the blanks to ATC Manufacturing, which stamped the final part with vertical flanges.

As with the rib, Boeing used a forming bladder and steel top and bottom tools. The bladder was changed to AZ31 magnesium, which better resists rupture versus aluminum. The C-channel tool was designed to operate within the Surface Generation PtFS forming cell to enable more rapid heating and cooling versus the conventional press with cartridge heaters used for the rib.

The C-channel tooling approach was developed to increase flexibility for multiple parts. The layup was placed onto the bottom tool, which was heated to the material's glass transition temperature (T_g) to maintain pliability without melting. A volume-reducing frame that included a pressure-sealing gasket was placed on top of the bottom tool, leaving a cavity slightly larger than the part layup (Fig. 5). Heat and hydraulic pressure were applied from the top tool through the bladder to the layup. Once at forming temperature, argon gas was applied to the bladder, forcing it down into the frame cavity to apply pressure to the tapered blank. The tool temperature was then increased through the melt phase of the material while maintaining bladder pressure, which prevented material from flowing across the lower tool while in melt phase.

> We are publishing lessons learned, enabling more informed trade studies … and establishing an open basis for industry discussion.

Preforming cycle time comprised 55 minutes for bladder and TP charge to reach process temperature, and 30 minutes to cool below the PEEK crystallization temperature. Pressure ranged from 1.4 to 9.7 bar and was maintained manually from a high-pressure tank with a valve. With the recent incorporation of a *pressclave* system into the PtFS cell, autoclave-like control of vacuum and pressure (±3 psi) in the press mold cavity will be automated in the future.

TP stamp-forming

Consolidated blanks for the -003 C-channel were sent to ATC Manufacturing for stamp-forming, in which the blank is heated sufficiently above melt temperature to ensure polymer flow. It was then transferred to a rapidly closing press to form and cool the part quickly. The forming tool in the press is kept at constant temperature, enabling rapid cycle times by eliminating ramp-up and cool-down. The tool temperature must be between melt temperature and T_g to develop the required level of thermoplastic matrix crystallinity in a short time, yet ensure the part can be removed without deformation. A series of blanks with implanted thermocouples was used to validate the complete thermal cycle for stamp-forming the C-channel.

Forming simulations using Aniform software (Enschede, Netherlands) showed the highly drapable PEEK fabric blank still posed a risk of wrinkling in compression areas, namely the inner (smaller radius) flange. Thus, a tensioning system (Fig. 5, p. 30) comprising shuttle plate and clips held the blank in tension as the matched metal tools closed to form it. Despite this, the flange face in compression still showed buckling as fiber was pushed inward at the inner radius. "All three RAPM tracks struggled to make this part," Hahn contends. "Its geometry was extreme, and not so indicative of a real part, but more designed to push what we could achieve in formability."

The manufacturing development trials led to challenge and transition parts that included multiple versions of the TP-RAPM-008 skin access panel, the TP-RAPM-013 rib with joggles on the flanges and a bladder study using three different geometries of the TP-RAPM-017 panel (Fig. 2, p. 26). Boeing St. Louis produced all of these except for the TP-RAPM-013 rib, which ATC produced. "Even though this part was made with UD tape, which is typically more challenging to form versus fabric, we were able to form these parts very well," says Trevor McCrae, R&D director for ATC Manufacturing. Overall, the TP forming trials showed that stamp-forming can produce complex geometries that might not be possible with conventional compression molding.

Learning to cut cost vs. aluminum

RAPM has demonstrated novel forming capability in all three tracks and amassed numerous lessons learned, ranging from how to position pad-ups to prevent slippage during compression molding to guidelines for part geometry to maximize quality and minimize tooling cost. "Understanding the effects of out-of-plane features, radius-to-thickness ratio and distance between geometric details becomes key as you move to small parts," Hahn observes. "Standardizing features such as radii, curves and flange angles can help mitigate cost drivers, for example, reducing tooling costs, the number of forming trials during development and the need for multiple scans during NDI [nondestructive inspection] by enabling a standard AUSS shoe for a family of parts."

Another cost driver RAPM highlighted was the time-consuming pre-consolidation step during TS prepreg compression molding. »

	Resin Infusion RI-RAPM-004 Deep Draw	Thermoset Prepreg TS-RAPM-012 Wave	Thermoplastic Forming TP-RAPM-013 Rib
Parts per Shipset	5	4	18
Weight Savings per Shipset	5.6 kg	1.8 kg *	3.5 kg
Recurring Cost Savings	67%	-7%	12%
Potential Savings over Life of Program	≈ $3,000,000	NA	≈ $900,000

*Opportunity exists to reduce weight an additional 0.5 kg via a more tailored preform.

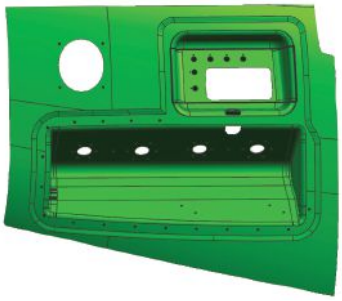
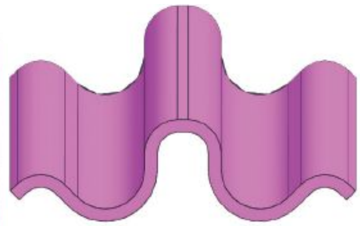
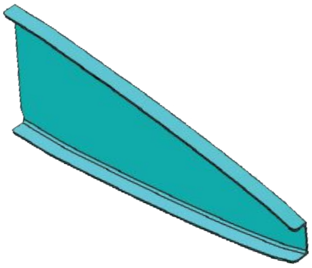




FIG. 6 Comparing cost vs. aluminum

RAPM calculated recurring manufacturing costs (e.g., materials, machine time) for selected challenge and transition parts, assuming non-recurring infrastructure was in place, and then compared these to machined aluminum.

"Low-bulk and higher resin content prepregs widen the process window and increase repeatability for high-quality parts," Hahn explains. "Solvay has developed a patent-pending 'transformer film' which can be applied to lower-impregnation prepregs before compression molding as a method of guaranteeing hydrostatic pressure in the mold cavity during consolidation."

Although RAPM won't officially end until fall 2020, followed by additional published results, findings so far for selected parts, which are based on real defense programs, show that composites *can* compete with machined aluminum (Fig. 6). Though the selected resin infusion and TP parts reduce recurring costs — e.g., materials, machine time, etc. calculated over total parts per family assuming non-recurring infrastructure is in place — the TS-RAPM-012 wave assembly actually shows a 7% *increase* versus machined aluminum. However, it does achieve desired *weight* savings, *and* at a premium that is actually within the margin mandated by Hendrix: "No one is going to pay 2X for the weight savings composites offer; they must cost within 10% of aluminum." However, he does concede, "There are still non-recurring time and cost issues to figure out, such as tooling and the development required to successfully form the shape."

LEARN MORE

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Read more about PtFS | short.compositesworld.com/RAPM-PtFS

Read about RAPM's complex geometry parts | short.compositesworld.com/RAPMparts

Expanding options

Although resin infusion wins for large parts, says Hahn, TS and TP stamping look pretty good for small parts. "Initial tooling cost for resin infusion is hard to overcome unless the metal parts are very complex, requiring a lot of machining," she explains.

"Thermoplastics look good for high volume, but a subcontractor for a given program might not be set up to do thermoplastics. However, thermoset stamping might be a very good option, even for low-volume replacement parts. Because defense applications are so wide-ranging, it is important to have more than one material and process in a trade discussion." Hahn notes that RAPM has opened up new materials and proven aerospace materials can work in automotive-type processes. "We also brought in new manufacturers."

Hendrix agrees that RAPM's aerospace and automotive manufacturing exchange was beneficial. Further, he was impressed with Solvay's and SGL's ability to form complex shapes without fiber distortion or other defects. "What it takes to make aesthetic auto parts actually has benefits," he concedes. "You can't have wrinkles or bad surface finish; they have to be perfect. But it still took multiple trials and significant development for them to form the RAPM parts. I'm not sure defense programs will want to invest in this non-recurring engineering if they're dealing with small quantities. The economics will be on a case-by-case basis, but tooling and development remain issues we need to address." Hahn adds, "We are publishing lessons learned, enabling more informed trade studies with expanded options and establishing a reasonably open basis for industry discussion." *CW* will continue this discussion with an update once RAPM wraps up later this year. CW

ABOUT THE AUTHOR

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Combination of automation, rigid foam core enable high-volume aircraft part production

A feasibility study demonstrates increased production capacity using Evonik foam core and automated manufacturing.

The aircraft industry uses carbon fiber/epoxy prepreg and honeycomb core for a variety of complex structural parts, such as wing access panels; wing flap track and fuselage belly fairings; leading and trailing edge parts; and spoilers, ailerons, winglets and landing gear doors.

However, according to Evonik Resource Efficiency GmbH (Essen, Germany), production of these parts cannot keep pace with market demand as aircraft OEMs seek to ramp up production rates over the next five to 10 years. The problem is two-fold: time-intensive hand layup processes, and production bottlenecks inherent to the use of traditional honeycomb core for sandwich composites. The open-cell structure of honeycomb core necessitates the use of potting materials to seal core edges and requires the application of an adhesive film to bond the core material to the laminate skins. A time-consuming, two-step curing process is also required to mold a honeycomb cored laminate.

As a solution to both problems, Evonik has been working with technology partners to study the feasibility of high-rate production of structural aircraft sandwich components using automated fiber placement (AFP) and automated tape laying (ATL) processes, and Evonik's ROHACELL HERO polymethacrylimide (PMI) structural foam as an alternative to honeycomb core.

ROHACELL HERO is a rigid, closed-cell, structural foam core material first introduced in 2013; certain grades now have Airbus AIMS (Airbus Industries Material Specification) 04-11-011 qualified flight approval as a core material. ROHACELL HERO's high compressive strength, Evonik says, enables the material to cope with compaction during handling by vacuum robot arms; the closed-cell foam material also eliminates the additional molding and potting steps that cause process bottlenecks with honeycomb.

Dornier 728 nose landing gear door.

Source | Evonik

In a feasibility study completed in 2019, Evonik worked with Deutsche Zentrum fur Luft-und Raumfahrt e.V. (DLR, Stade, Germany), the national research center for aeronautics and space, along with Airbus subsidiary Composite Technology Centre GmbH (CTC, Stade), which specializes in composite processing technologies.

The study built on findings from a 2014 project from CTC that studied material options for out-of-autoclave (OOA) hand lay-up production of a Dornier 728 nose landing gear door part, and found that Evonik's PMI foam core sandwiched between carbon fiber/epoxy faceskins was 25% less expensive to produce and weighed 19% less than a carbon fiber/epoxy prepreg and honeycomb core design. The 2019 study set out to automate construction of the Dornier 728 part for high-volume production.

For the new study, carbon fiber/epoxy prepreg sandwich part preforming production trials were carried out at DLR's EVo plant, which is a highly flexible, fully automated production line. The EVo plant is fitted with conventional vacuum gripper robot arms for handling cut-to-size glass fiber and carbon fiber fabrics, tapes, lightning strike protection meshes and foam cores.

According to Evonik, study results demonstrated 65% less mold tool utilization time compared to manual production of the same part. For aircraft part manufacturers, this effectively doubles production capacity, providing part output rates that Evonik says are unachievable with a honeycomb core using the same tooling. The trial demonstrated that it is possible to use automation to significantly reduce the overall production steps and time needed to manufacture the Dornier 728 nose landing gear door using ROHACELL HERO as the sandwich foam core material instead of an equivalent grade honeycomb core. An additional cost benefit was that EVo's current automation equipment, which would have needed adaptations to handle a honeycomb core, did not need to be adapted to support the ROHACELL foam core part. Based on mechanical properties from the Fraunhofer IWM Institute in Halle, Germany, Evonik says that ROHACELL HERO also provides the same level of damage resistance and visual inspection detectability as an equivalent aircraft structural grade honeycomb core.

Evonik aims to take these processes and material to high-volume aircraft part production. CW

Composites Events

Editor's note: Events listed here are current as of April 7, 2020. Visit short.compositesworld.com/events for up-to-date information.

April 29 - May 1, 2020 — VIRTUAL
CW ACMA Thermoplastic Composites Conference
acmanet.org/TCC20

May 4-7, 2020 — Seattle, Wash., U.S. — CANCELLED
SAMPE 2020
sampeamerica.org

May 12-14, 2020 — Paris, France — CANCELLED
JEC World 2020
jec-world.events

May 19-21, 2020 — VIRTUAL
ACMA Composites Recycling Conference
cvent.com/events/composites-recycling-conference-2020

June 1-4, 2020 — Denver, Colo., U.S. — CANCELLED
AWEA WINDPOWER 2020 Conference & Exhibition
engage.awea.org/events

June 4-6, 2020 — Beijing, China
SAMPE China
sampechina.org

June 9-11, 2020 — Stockholm, Sweden
AMC European Carbon Materials and Technology Conference
advancedmaterialscongress.org/ecmt20

June 14-18, 2020 — Houston, Texas, U.S. — NEW DATES
Corrosion 2020 Conference & Expo
nacecorrosion.org

June 23-25, 2020 — Moscow, Russia — NEW DATES
COMPOSITE-EXPO
composite-expo.com

July 19-25, 2020 — Prague, Czech Republic
ICCE-28
icce-nano.org

Aug. 25-26, 2020 — Detroit, Mich., U.S.
Automotive Lightweight Materials Joining, Forming and Manufacturing Innovation 2020 Summit
global-lightweight-vehicle-manufacturing.com

Aug. 25-27, 2020 — Novi, Mich., U.S.
Foam Expo North America
foam-expo.com

Aug. 31 - Sept. 2, 2020 — Hamburg, Germany
9th International Conference on Advances in Rotor Blades for Wind Turbines
iqpc.com/events-wind-rotor-blades

Sept. 8-11, 2020 — Istanbul, Turkey
METYX Fifth Composites Summit
metyx.com/metyx-fifth-composites-summit

Sept. 9-11, 2020 — Novi, Mich., U.S.
SPE ACCE
SPEautomotive.com/acce-conference

Sept. 15-16, 2020 — Chicago, Ill., U.S.
Additive Manufacturing Conference
additiveconference.com

Sept. 21-24, 2020 — Orlando, Fla., U.S.
CW CAMX 2020
thecamx.org

Sept. 22-23, 2020 — Cleveland, Ohio, U.S.
Ceramics Expo 2020
ceramicsexpousa.com

Sept. 29 - Oct. 1, 2020 — Tampa, Fla., U.S.
IBEX
ibexshow.com

Oct. 13-14, 2020 — Bremen, Germany
ITHEC 2020: 5th International Conference and Exhibition on Thermoplastic Composites 2018
ithec.de/home

Nov. 10-12, 2020 — Stuttgart, Germany
Composites Europe
composites-europe.com

Nov. 10-12, 2020 — Stuttgart, Germany
Lightweight Technologies Forum
lite-forum.com/en/

Nov. 17-19, 2020 — Salt Lake City, Utah, U.S.
CW Carbon Fiber Conference 2020
carbonfiberevent.com

New Products

Source | Hexcel

» ADHESIVES & BONDING

Low-temperature-cure adhesive targets marine applications

Hexcel (Stamford, Conn., U.S.) has launched its new low-temperature, fast-cure HexBond 679 adhesive film. HexBond 679, says Hexcel, delivers strong bonding performance in sandwich structures and offers significant cycle time reductions with its short-cure cycles at low temperatures.

Formulated specifically to meet the low-temperature cure requirements of marine and industrial applications, HexBond 679 is a 250-gsm supported epoxy adhesive film that is fully compatible with the HexPly M79 prepreg range. Curing in four hours at 80°C/176°F or eight hours at 70°C/158°F, HexBond 679 films are said to provide extremely high lap shear and peel strength performance, as well as shelf-life of up to six weeks at 23°C.

Hexcel says HexPly M79 prepregs and HexBond 679 adhesive films allow boatbuilders to increase build rates with reduced heating and cooling times. When combined with Hexcel's air venting Grid Technology HexPly M79, unidirectional (UD) carbon tapes can be laminated with reduced debulking steps to produce porosity of <1%, regardless of laminate thickness.

HexBond 679 adhesive film has also received DNV-GL Type approval as part of Hexcel's latest accreditation program, providing vessel manufacturers with additional independent assurance of the product's quality, performance and consistency.

hexcel.com

LEARN MORE

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short.compositesworld.com/CWproducts

Source | Saint-Gobain Abrasives

» SURFACE POLISH/PASTE

Buffing wheels use minimal compound to maximize product life

Saint-Gobain Abrasives' Norton FAB (fixed abrasive buff) buffing wheels are said to operate with a significantly decreased need for buffing compounds. Their design incorporates abrasive grains into the buffing wheel, resulting in Ra values ranging from 1 to 5 Ra. The wheels are tear-resistant and waterproof, enabling a longer life than traditional cotton buffs, the company says. The wheels are said to be suitable for some composite materials including those with a polyurethane surface.

The Norton FAB is intended to provide efficient, safe buffing with minimal clean-up. With less compound to purchase, apply and dispose of, costs are minimized and environmental impact is reduced.

A premium silicon carbide abrasive is uniformly applied to both sides of the cloth for a more consistent buffing performance. Norton FAB wheels can be easily incorporated into new or existing robotic buffing applications.

Key applications include automatic or semi-automatic buffing, cut buffing and mush buffing in a range of markets such as automotive, hardware, oil and gas and more.

Norton FAB Wheels are available in outer diameters from 5" to 22", in 12 or 16 ply (number of cloth layers of buff), two or four pack (waviness of the buff face) and various ID hole designs.

nortonabrasives.com

» THERMOPLASTIC SOLUTIONS

Thermoplastic composite material demonstrates fire resistance for EVs

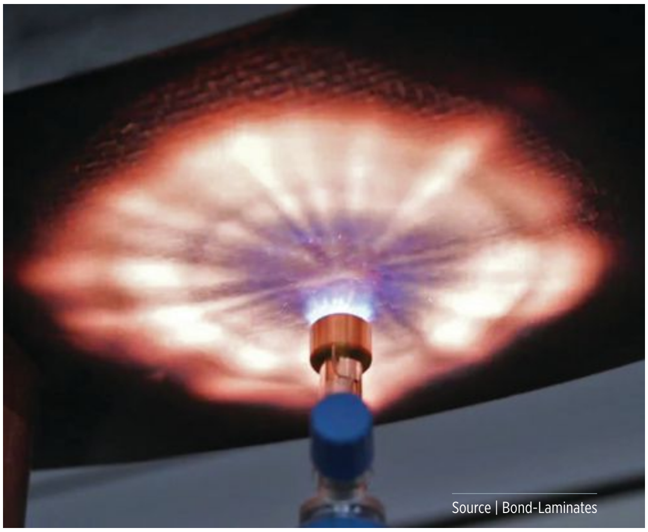
Bond-Laminates' Tepex continuous-fiber-reinforced thermoplastic composite materials have structures designed to resist fire without flame-retardant additives. This is a result of tests conducted by the LANXESS subsidiary partly in cooperation with external testing institutes.

According to the company, the tests also showed that these composite materials are highly suitable for structural components and housing components in high-voltage batteries for electric vehicles, which, for safety reasons, need to have excellent flame-retardant properties. The materials present a lightweight alternative to aluminum and enable cost-effective component solutions due to the cost-reducing integration of functions and simple processing in the hybrid molding method without need for rework.

Non-flame-retardant Tepex variants were tested in a fire pan test in which the specimen lies flat over a tub of burning fuel and is exposed to the fire directly for 70 seconds and less directly for 60 seconds. This test is a realistic reflection of the fire situations Tepex might face in typical applications such as underbody paneling components, Bond-Laminates says.

With electric vehicle powertrains in mind, Bond-Laminates has tested the fire behavior of overmolded, polyamide 6-based Tepex. A "HiAnt carrier" was used. This is a U-shaped profile made of Tepex, the inside of which is reinforced with crosswise ribs made of various polyamide 6 types such as Durethan, with or without a flame-retardant package. The specimen is exposed to a 900°C flame in six positions for between 30 seconds and 5 minutes, including on the polyamide ribs and areas that have not been overmolded.

Using non-flame-retardant Tepex with a flame-retardant injection molding material offers a substantial safety margin for the design of flame-retardant components, Bond-Laminates says. The company sees potential for this material combination to be applied in high-voltage battery components such as housings and partitions, but also in floor plates for inductive battery charging systems.


Source | Bond-Laminates

Tepex with inherent flame-retardant properties exhibits:

- A fabric structure and high fiber content that prevents flames from spreading.
- Flame-retardant product variants with UL 94 V-0 classification.
- Suitability for use in flame-resistant, high-voltage battery components and inductive charging.

bond-laminates.com
lanxess.com


Source | CRP Technology

» GLASS FIBER / ADDITIVE MANUFACTURING

Flame-retardant, glass fiber-reinforced material made for selective laser sintering

CRP Technology's Windform FR2 is a flame-retardant, halogen-free polyamide-based glass fiber-reinforced material that combines improved wear resistance and temperature resistance.

Compared to Windform FR1, FR2 is not electrically conductive and enables better detail resolution with a smoother surface finish, the company says. It is suitable for aerospace applications, automotive parts (casings of electrical and electronic components, housing and enclosure assemblies), consumer goods (lighting, appliances) or any part that requires flame retardancy.

Windform FR2 passed the FAR 25.853 12-second vertical and 15-second horizontal flammability tests as well as the 45° Bunsen burner test and smoke density test.

crp-group.com

» MACHINING ACCESSORIES

Finishing tools prevent delamination in hybrid material machining

Source | Seco Tools

Seco Tools' JC899 Hybrid Stack finisher and JC898 rougher are solutions for aerospace shops with holemaking and milling operations in hybrid stacked materials. Together with the JC898 rougher, the JC899 finisher offers three to six times more tool life over conventional drill/reamer combinations, the company says.

The JC898 rougher has a frontal teeth design suitable for helical interpolation, which reduces cutting forces and minimizes the risk of delamination when working with hybrid stacked materials that put pressure on Z-axis drilling operations and generate chips that can damage the machined hole's surface finish.

The JC899 finisher's diamond-based coating enables reliable processes and high-quality products, while the double geometry's left-hand helix prevents delamination, fiber pullout and chip marks from damaging the workpiece's surface.

The JC898 and JC899 are said to reduce post-machining work to simplify CFRP-titanium and CFRP-aluminum hybrid material holemaking operations. The resulting processes are said to be twice as fast as those performed with alternative solutions.

In addition, the JC898 and JC899 are suited for helical interpolation and side milling applications, increasing process stability and speed, while minimizing the need for post-machining operations and benchwork.

The JC898 and JC899 handle lengths or stack heights ranging from 15 to 60 mm. The JC898 is available in diameters of 8 or 15 mm, while the JC899 is available in 8.5 and 14.8 mm as well as in a 0.375" diameter.

secotools.com

» THERMOSET RESINS & ADHESIVE SYSTEMS

Low-profile resin designed for cosmetics, low shrinkage

Aropol LP 67400, **INEOS Composites**' (Dublin, Ohio, U.S.) low-profile unsaturated polyester resin, is designed for the recreational marine and vehicle markets in North America. It has low shrink and attention to cosmetics with high strength and robust processing capabilities for boat builders and RV manufacturers, the company says.

This resin is made to be used in room temperature, closed-molding applications such as infusion, light resin transfer molding (LRTM) and press-molding. It is suited for above-water-line marine and pontoon small parts, as well as RV parts.

INEOS says Aropol enables room temperature processing, improved mechanical properties, lower exotherms and improved storage stability as compared to traditional low-profile resins. This resin also features shrinkage control and dimensional stability over a variety of part thicknesses.

ineos.com

Source | 3M

» BONDING

Low surface energy tape provides solution for difficult-to-bond materials

3M's (Saint Paul, Minn., U.S.) VHB tape LSE series is designed to eliminate design challenges associated with difficult-to-stick-to composites and low surface energy (LSE) plastics.

The tape works as a bonding solution for LSE substrates like polypropylene, thermoplastic olefins and thermoplastic elastomers, as well as composite materials like fiber-reinforced plastic. Made of double-sided acrylic foam, it creates a long-lasting, high-strength bond across a wide temperature range. This provides a durable alternative to ultrasonic welding and other adhesion methods, 3M says.

The 3M VHB tape LSE series is made to:

- Bond without primer to difficult-to-bond-to substrates
- Increase speed and productivity
- Reduce the use of chemicals, like primers, which can contain volatile organic compounds or chemicals of concern
- Offer long-term durability outdoors
- Provide greater design flexibility
- Lower manufacturing costs

The 3M VHB Tape LSE Series enables high initial tack at low temperatures with faster and more reliable bonds in cold environments, such as outdoor applications or unheated factory floors. This low-temperature capability also enables immediate handling strength in various environments, eliminating time spent waiting to continue through the production process.

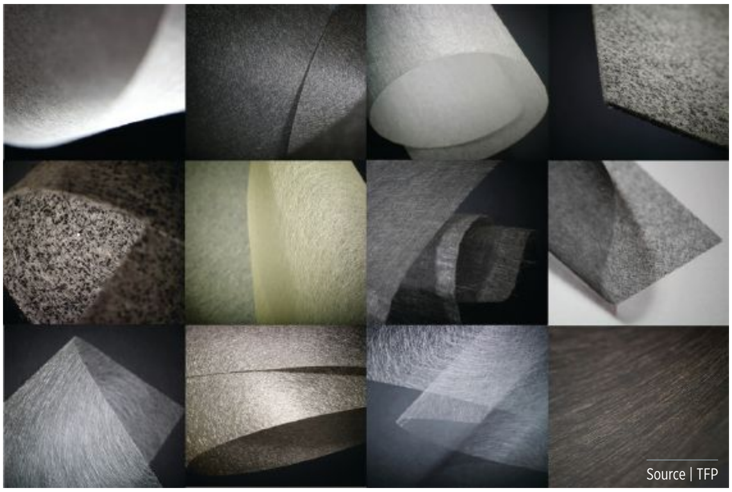
The LSE series' acrylic construction resists cycling temperatures, exposure to UV light, moisture and solvents. Its holding power under a wide temperature range makes it a durable alternative to rivets, ultrasonic welds and liquid adhesives.

While designed specifically to meet the needs of low surface energies, the LSE Series also bonds well on medium surface energy plastics, metals and more. It can be applied by hand, with semi-automatic equipment or robotics. The new tape is available in thicknesses of 0.6, 1.1 and 1.6 mm.

3M.com

» FIRE-RESISTANT MATERIALS

Lightweight veils target high-temperature applications



Source | TFP

Technical Fibre Products' (TFP; Burneside, U.K.) polyimide and basalt lightweight veils are designed for high-temperature performance in composites. Part of TFP's OPTIVEIL range, the new veils have been developed specifically to expand TFP's selection of high-temperature materials.

The polyimide veil is the highest temperature-stable polymer veil that TFP manufactures, with a maximum service temperature of more than 260°C, which, TFP says, is significantly higher than that of other polymers such as polyester and PPS. The material was developed as a high-performance insulation material for space applications, designed to offer the temperature stability necessary to withstand missions to Mercury and the sun.

The basalt veil has been developed as a more temperature-stable alternative to TFP's standard E and ECR glass veils. It is stable up to 850°C and retains its integrity when in contact with an open flame, making it suitable for applications requiring a fire barrier. Basalt, like glass, also has a high resistance to acid and alkali, which makes it ideal for use in corrosive environments.

As well as increased temperature stability, these new materials are said to offer the uniformity and surface quality synonymous with TFP's OPTIVEIL and OPTIMAT ranges, which include carbon, glass, metal coated, aramid, recycled carbon and thermoplastic nonwovens. This quality of dispersion reportedly makes the materials suitable for a wide range of composite applications including surface finish, improving resin flow, adhesive carriers and imparting functionality where required. **tfpglobal.com**

» ADDITIVE MANUFACTURING

On-demand 3D printing program

Arevo's (Santa Clara, Calif., U.S.) MaaS program has been developed for on-demand production of ultra-strong, lightweight 3D-printed composite parts. In addition to its availability in the U.S., MaaS is also offered in Japan in partnership with AGC Inc. and new partner 3DPC. This service is based on Arevo's Aqua platform, said to be the world's first industrial-grade continuous fiber 3D printing system capable of printing parts of up to 1 m^3. The system also features Xplorator software — said to be the industry's first fully integrated composite tool chain to accelerate the design process from concept to production.

The MaaS platform is designed to provide composite parts with unprecedented low cost and true production scale for 3D-printed goods and reduced design cycles for a wide range of products.

arevo.com

MANUFACTURING SUPPLIERS

SHOWCASE

ADVERTISING INDEX

Tooling, precision enable composites in satellite subsystems

■ **Building block approach**

Satellite parts, such as this reflector dish supporting structure, are cut from a flat sandwich construction panel made up of core material between two carbon fiber skins.

Source | MDA

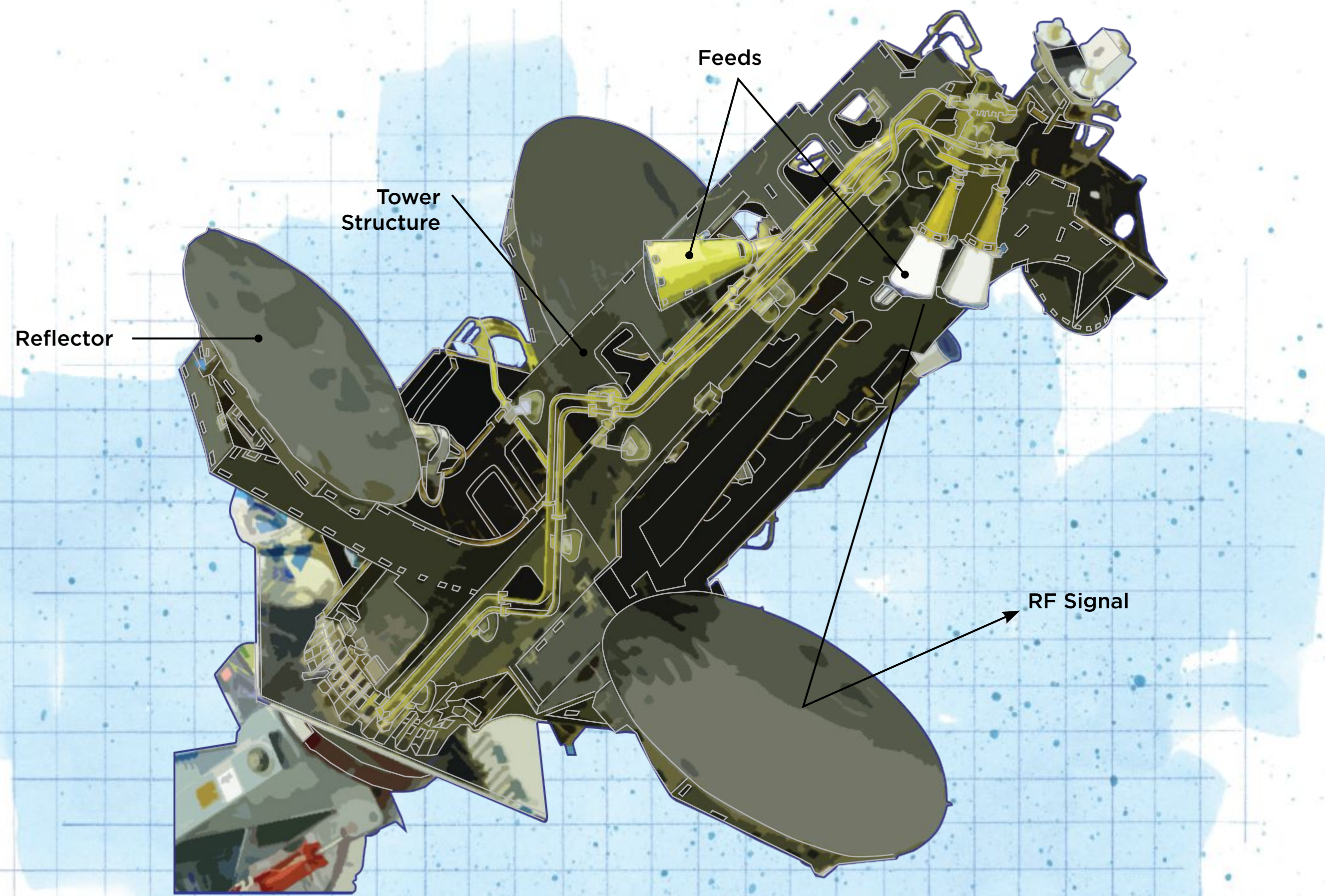
Tight tolerances drive design and engineering of large-format composite component and dishes to create unique satellite structures.

By Scott Francis / Senior Editor

» MDA Corp. (MDA, Vancouver, British Columbia, Canada), specializes in commercial space intelligence and communications applications, from space robotics to advanced surveillance and intelligence solutions. MDA's satellite products include a variety of designs that cover a wide range of single-beam and multi-beam antenna systems, and serve a variety of markets including commercial, space and military. Applications enabled by MDA antennas include broadband multimedia, fixed service, mobile communications, remote sensing missions, telemetry and navigation. MDA's Sainte-Anne-de-Bellevue, Quebec, Canada, location designs composites-intensive satellite antenna subsystems for the company's various satellite designs.

To build these subsystems, which include the reflector dishes themselves and various other composite parts, Steven Payette, composites manufacturing engineer for MDA Sainte-Anne-de-Bellevue, says the company uses "a building block style" approach.

The work at MDA's Sainte-Anne-de-Bellevue facility focuses largely on engineering and design. MDA designs 3D models for each antenna, engineers the parts and designs the tooling. Most of the composite parts are produced out-of-house with industry partner STELIA North America (Mirabel, Quebec, Canada), which



DESIGN RESULTS / **Geosynchronous Satellite Antenna Subsystem**

- Supporting structures including towers, bases and reflector dish backing structures are cut from flat panels of carbon fiber/honeycomb core in a sandwich construction
- Each cell of the honeycomb core is vented so no air is trapped in the part when it is launched into space
- Contours are designed into the surface of geosynchronous satellite reflector dishes to concentrate or disperse RF waves based on targeted geographic locations

Susan Kraus / Illustration

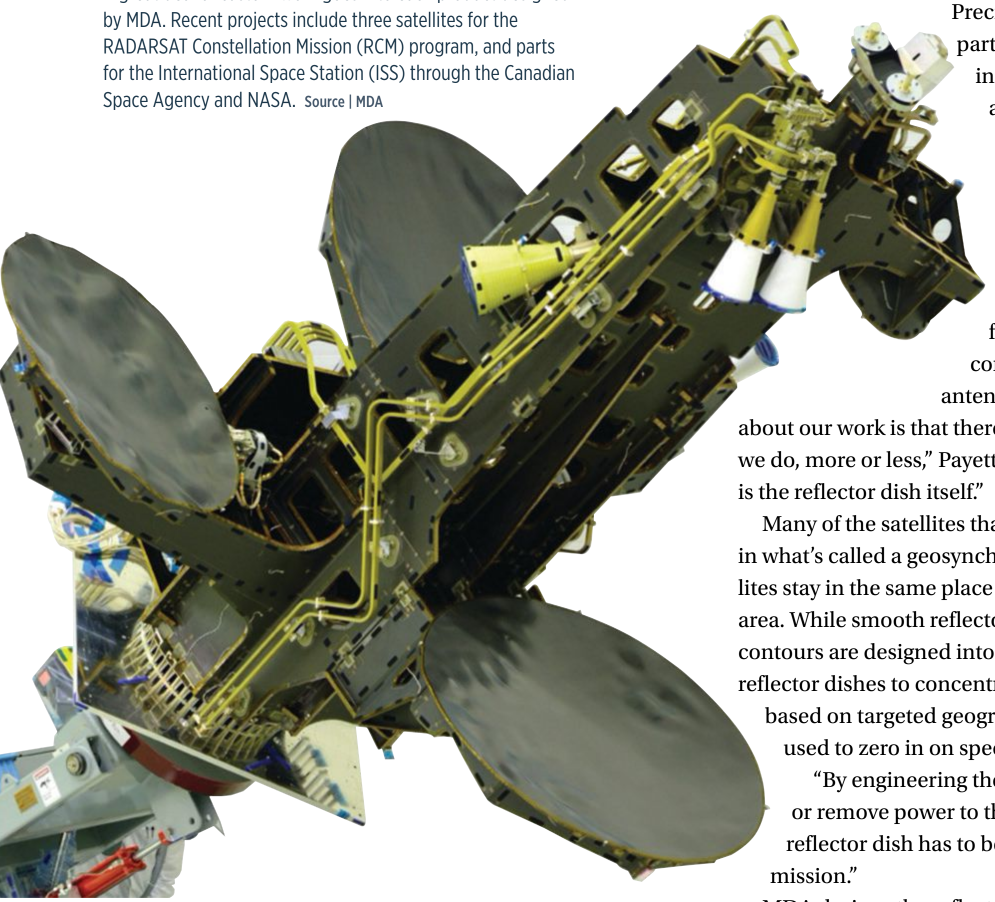
manufactures the composite parts for the satellites. The parts, which are made from Kevlar or aluminum honeycomb core with carbon fiber prepreg skins, are then brought in-house, where MDA performs room temperature bonding to assemble the myriad composite structures together, followed by precision trimming, critical alignment, the addition of metallic fasteners or fittings, and a battery of tests to ensure flight readiness.

"So what we'll get from STELIA is a flat panel with a bunch of strange shapes cut out of it," Payette explains (see opening photo, p. 44). "STELIA will machine through the laminate and leave the core in place, and we'll cut out the pieces — almost like a model airplane, where all the parts come on a plastic rack and you've got to cut them out."

According to Payette, pieces are cut from these flat panels and used to assemble such structures as towers, bases and backing structures for reflector dishes. The position and the shape of the parts is what drives the performance. MDA designs the parts to be oversized and then performs custom dry fitting and precision machining to get everything in the exact position needed for the final shape for each unique antenna structure.

"The ratio is something like three engineers per one guy on the floor building things," Payette says. "Every time we get a new product, somebody with a background in either electrical engineering or physics does the RF design and goes through, 'what do the shapes of these things need to be?' Then you have a mechanical designer who goes through, 'how does this work from a packaging point of view to get it into the spacecraft and onto the spacecraft bus?' Next, a structural engineer asks, 'what does it have to look like to survive launch and to survive operation?' Someone with a background in thermal engineering says, 'what's it going to look like »

One-of-a-kind structures



A great deal of custom work goes into each product designed by MDA. Recent projects include three satellites for the RADARSAT Constellation Mission (RCM) program, and parts for the International Space Station (ISS) through the Canadian Space Agency and NASA. Source | MDA

at 150°C or -150°C?' And on down the line until finally, you get to the person who says, 'okay, how are we going to put it all together?'"

Precision is a key part of MDA's process for each part. Because the parts will ultimately operate in the vacuum of space, honeycomb cores are vented so every hole is connected to the next and no air is trapped in the part when it is launched into space. "We have to pierce holes in between every cell of the core," Payette says. "Otherwise [the vacuum] would just pop the skins off."

While many of the components start from the standardized shapes cut from composite panels described above, each antenna subsystem is unique. "What's interesting about our work is that there's little volume. We make one of everything we do, more or less," Payette says. "The unique part for every assembly is the reflector dish itself."

Many of the satellites that MDA provides antennas for are placed in what's called a geosynchronous orbit. Geosynchronous satellites stay in the same place relative to the Earth and service a specific area. While smooth reflectors are used for steerable satellite dishes, contours are designed into the surface of geosynchronous satellite reflector dishes to concentrate or disperse radio frequency (RF) waves based on targeted geographic locations. Multiple dishes may be used to zero in on specific regions within the targeted area.

"By engineering these shapes into the reflector dishes, we add or remove power to the different regions," Payette says. "Each reflector dish has to be unique, and the shape changes for every mission."

MDA designs the reflector dish mold. The mold is manufactured by PCM Innovation (Montréal, Canada) and is then sent to STELIA to build the dish. The tooling for the reflector dishes has to be exact.

Vented core

Each cell of the honeycomb core must be vented to create a pathway for air to escape in the vacuum of space. Source | MDA

Reflector dishes

Unique tooling must be designed for each geosynchronous satellite dish (shown above) in order to create the contours needed to target specific geographic locations. There is indeed that much shape on the surface of these dishes, which can also be seen on the structure shown on p. 46. MDA designs parts oversized and then machines them to tight tolerances to create each unique antenna structure (shown left).

Source | MDA

MDA's products have tight dimensional tolerances because the final shape affects the satellite's electrical performance. Molds are made one of two ways: They are either machined from monolithic graphite blocks, or are laid up using prepreg or a dry fiber infused with an epoxy.

"As you can imagine, we are the mold supplier's favorite customer, because we need new molds all the time," Payette says. "Unlike an aerospace company pulling hundreds of parts off the same mold, we generally use each mold for only one part."

In addition to the tooling, the material used also plays a large role in the ability of each reflector dish to precisely target specific locations. The materials used to fabricate the reflector dishes and supporting structures need to be very stable over a wide temperature range. According to Payette, the satellites can experience temperatures anywhere between 175°C and -175°C.

"We use composites specifically because they're very dimensionally stable," he says. "We need something that doesn't move."

Toray Advanced Composites (Morgan Hill, Calif., U.S.) is the main carbon fiber prepreg supplier for MDA's parts. Less critical structures on the satellites are constructed from carbon fiber/epoxy prepreg. More critical structures, including the reflector dishes, use a carbon fiber/cyanate ester prepreg.

Testing is another big part of the work done at MDA's Sainte-Anne-de-Bellevue facility. Each product goes through thermal testing of hot/cold temperature cycling to simulate the extreme temperature fluctuations the satellite will experience in space. Mechanical assessments are also performed and include vibration and acoustic testing. The majority of the testing is performed in-house. MDA has thermal vacuum chambers up to 13 by 13 feet, and the company has two vibration tables for vibration testing.

A great deal of custom work goes into each product designed by MDA. The company recently built and launched the RADARSAT Constellation Mission (RCM), a program consisting of three identical Synthetic Aperture Radar (C-Band) Earth observation satellites designed for remote sensing of the Canadian north, and has also created parts for the International Space Station (ISS) through the Canadian Space Agency and NASA. For some of MDA's projects, prototypes are created for testing ahead of time, but Payette points out that even then, all flight products go through an aggressive testing campaign.

"Nobody likes to spend money to send things into space without already knowing that they're going to work," he says. CW

LEARN MORE

Read this article online | short.compositesworld.com/MDA_sat

ABOUT THE AUTHOR

Scott Francis, senior editor for *CompositesWorld*, has worked in publishing and media since 2001. He's edited for numerous publications including *Writer's Digest*, *HOW* and *Popular Woodworking* and *Products Finishing*.

Post Cure

Highlighting the behind-the-scenes of composites manufacturing

Source | Suzlon Energy Ltd.

Undercover

This wind turbine nacelle top cover (an inner view shown here) manufactured by Suzlon Energy Ltd. (Pune, India) is reinforced by multiple grid and lattice ribs comprising structural-grade glass fiber noncrimp fabric and grid-scored foam core with woven scrim on top, processed in a single-step vacuum infusion molding process. This nacelle cover's design and manufacturing method won an ICERP-JEC Composites Innovation Award in 2019.

Show us what you have!

The *CompositesWorld* team wants to feature your composite part, manufacturing process or facility in next month's issue.

Send an image and caption to *CW* Associate Editor Hannah Mason at hmason@compositesworld.com, or connect with us on social media.

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