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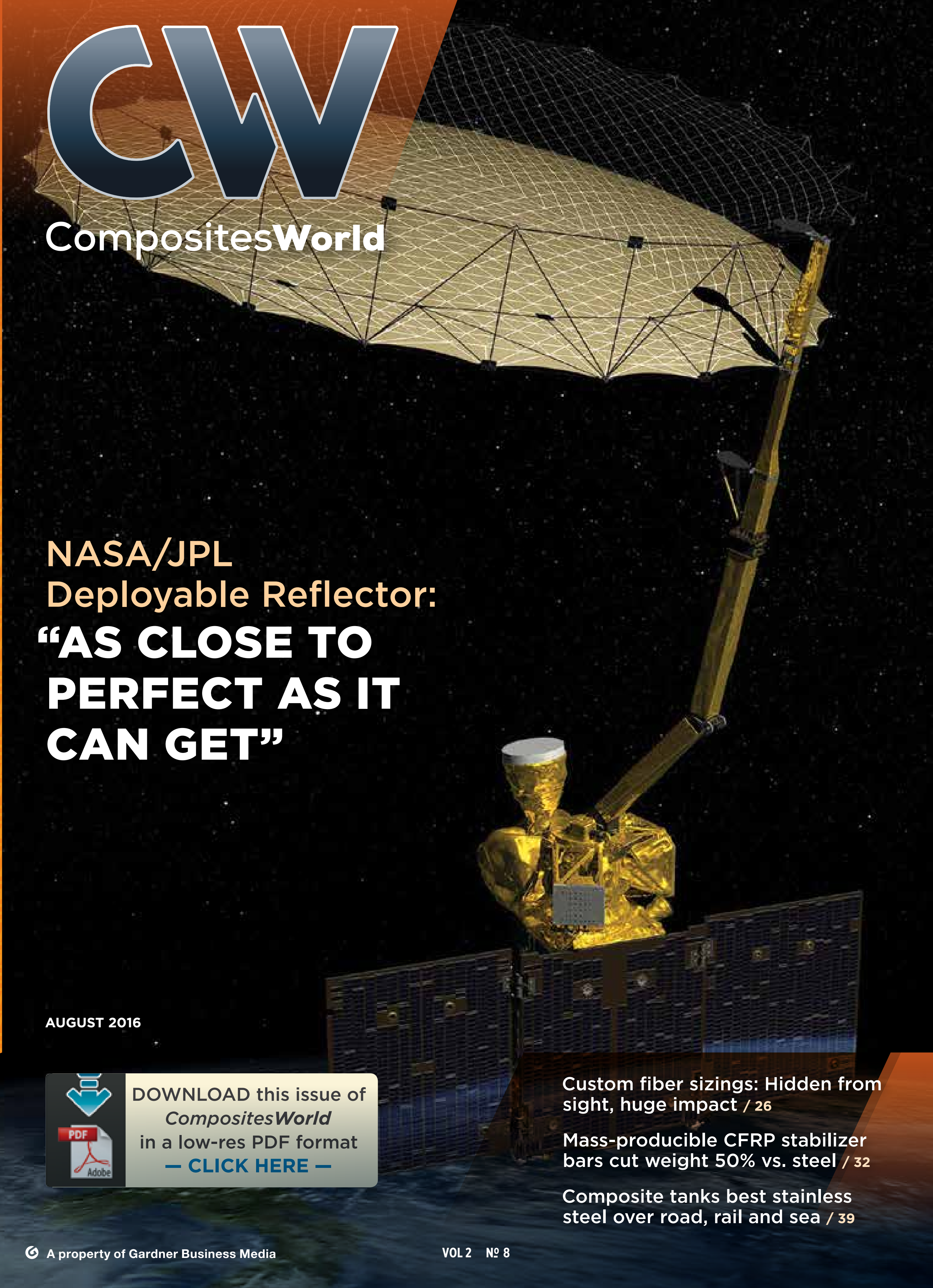

NASA/JPL Deployable Reflector: "AS CLOSE TO PERFECT AS IT CAN GET"

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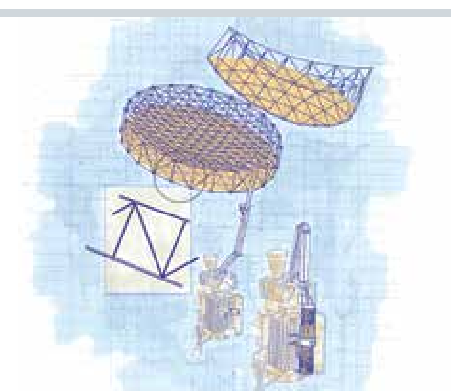
» ON THE COVER

In 2015, NASA's Jet Propulsion Laboratory (JPL, Pasadena, CA, US) launched the Soil Moisture Active/Passive (SMAP) mission to measure ocean salinity and soil moisture from low-Earth orbit (LEO). SMAP's single spacecraft features a 6m mesh reflector dish made of a collapsible circular composite that permitted launch into LEO, then deployment to full size for operation. Read more about the reflector's design on p. 44.

Source / Northrop Grumman

FOCUS ON DESIGN



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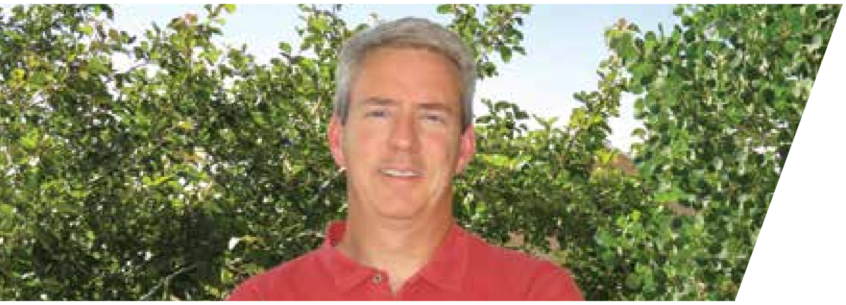

It's been more than a decade since I first heard about the possibility of my refrigerator, dishwasher, thermostat, toaster or teapot being plugged into the Internet. I was at a housewares tradeshow in Chicago, for my previous job, and Internet-capable appliances were touted there as the next line of products destined to make human life better and easier. I can't remember how they were going to make my life better, but there seemed to be no end of enthusiasm for the concept.

> Imagining the utility of IoT in our increasingly data-driven age.

If you missed that wave of Internet-based excitement, don't worry, because it's back, with new terminology, new application, and — thankfully — actual utility. The terminology you've probably heard already: Industry 4.0, Internet of Things (IoT), Fourth Industrial Revolution, Cyber-Physical Systems (CPS). For simplicity, I'll stick with IoT.

The principle of IoT can be boiled down to one basic idea: The exchange of data among devices to enhance device performance and expedite decision-making. In this way, IoT has utility in myriad places, including consumer products (refrigerator!), energy networks, transportation networks, buildings and homes, healthcare and, of course, manufacturing. And, more specifically, composites manufacturing.

IoT in composites manufacturing is especially appealing; our industry's long history of dependence on manual labor (hand layup, sprayup), followed by a rapid migration to automation today, begs for the kind of data that IoT offers. Such data allow people and manufacturing systems to track, manage and act on the material and machinery variables for which the composites industry is famous/infamous, thereby giving fabricators just a little more control over their manufacturing processes.

There is, however, one aspect of IoT in composites fabrication that is only just now starting to come to life, and I believe it has the potential to have a profound effect on the quality and efficiency with which we make our products. I will call this IoT tool in-situ quality control, or, IQS if you prefer.

One thing we often overlook when we think and talk about composites is that it is one of the very few materials that is actually made during part production. That is, a composite is comprised of two or more constituent materials that are not combined until part fabrication is begun. This means that from the moment liquefied resin comes in contact with fiber, we have not only started making a composite part or structure, but we have also started making the final composite material. Which, in many ways — particularly if you're used to working with steel, aluminum or other amorphous materials — is crazy. It means that from the get-go we *intentionally* introduce variables (two dissimilar materials) that are *destined* to affect (potentially negatively) final part quality.

Overcoming these variables used to require a mix of knowledge, experience, faith and luck that is unnecessary in many other manufacturing processes. And when everything was going your way, those variables came together to make a beautiful composite structure, but when knowledge, experience, faith or luck fell short, you were left with a very expensive mistake.

IQS, which is being developed by several suppliers, is an emerging technology realm that offers composites fabricators a chance to, basically, check their work as they go. IQS, in the form of video, nondestructive evaluation and other technologies, will check for gaps, wrinkles, bridging, voids, foreign object debris, delamination, waviness, resin richness, dimensional accuracy and more. IQS will help you identify problems when they are easier and less expensive to fix. IQS will jump in when knowledge, experience, faith or luck struggle.

Your refrigerator may or may not be surfing the Internet soon, but on the shop floor, IoT has real utility and application to help make composites manufacturing quality more reliable and consistent.

JEFF SLOAN — Editor-In-Chief


JUMP IN!
The water is fine.

How to win in carbon composites for the automotive market

» Carbon fiber has emerged as one of the promising options as automakers work hard to reduce vehicle weight to meet US corporate average fuel economy (CAFE) and European Union (EU) carbon dioxide (CO_2) gas emission requirements. As more carbon composites are used for automotive applications, the future of the composites industry looks bright. Most important, the global carbon composites industry is about to enter a period of wide-ranging and transformative change, as demands continue to shift and environmental regulations tighten.

Companies that want to have long-term growth need to develop strategies that respond to this critical trend without delay. This article offers a perspective on what needs to be done to grow the potential of carbon composites in the auto industry. It is based on many discussions and interviews with original equipment manufacturers (OEMs) and composite parts fabricators across various end-use applications in the automotive market.

Global Carbon Composites End Product Market Forecast in Automotive Industry (2015-2021) (US$Bn)

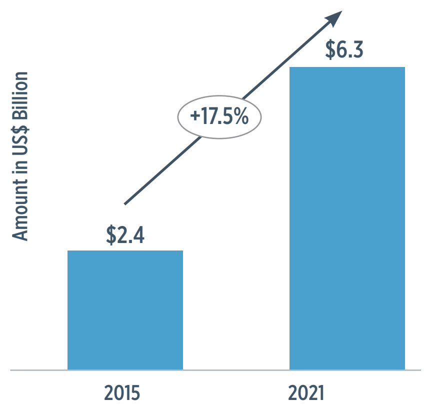

Fig. 1 Auto industry opportunities forecast

The autocomposites market is expected to grow to US$6.3 billion in 2021, with a compound average growth rate (CAGR) of 17%.

Source | Lucintel

In fiscal year 2015, worldwide demand for carbon composite products in the automotive industry — roof panels, body frame, closure panels and more — reached a value of US$2.4 billion. The market is expected to grow to US$6.3 billion in 2021, with a compound average growth rate (CAGR) of 17% (see Fig. 1). This growth in global carbon composites will be due largely to strong demand for carbon fiber-reinforced plastics (CFRP) in luxury cars, race cars and other high-performance cars.

Government regulation of fuel efficiency and stringent policies concerning CO_2 emissions are putting pressure on OEMs to make their vehicles lighter without compromising occupant safety. For example, by 2020 it will be necessary in the EU to restrict vehicle CO_2 emissions to 95 g/km. The current regulatory threshold is about 132.2 g/km. Similarly, in the US, CAFE regulation dictates an OEM's car and light-truck fleet-wide average fuel efficiency be 54.5 miles per gallon or equivalent (mpge), or 23.1 km/L, by 2025. The current average is about 28 mpge (11.6 km/L).

Of all the material options, only CFRP offers the potential for weight savings greater than 50%.

This challenge has opened an opportunity for the development of stronger and lighter automotive equipment and spare parts. When Lucintel spoke to engineers at automotive OEMs about lightweighting requirements, they responded that they are required to develop automotive structural parts with 50% weight-saving potential. Due to this, they are looking into lightweight materials, such as advanced high-strength steel (AHSS, steel with tensile strength that exceeds 780 MPa), aluminum, magnesium and CFRP for their product design. Of all the material options, only CFRP offers the potential for weight savings greater than 50%. For that reason, this advanced material is receiving great attention. Currently, most major automakers, such as BMW, Mercedes, Ford and GM, are focusing on incorporating CFRP in mass-volume cars as a means to meet the stringent government guidelines.

Perhaps the biggest trend in the automotive industry is the development of transformative technologies and material systems to make carbon fiber parts for mass-volume vehicles. The future will not play out the same way for every segment of the automotive industry or type of application or type of material, so suppliers need to develop suitable strategies and a road map to drive success in their business.

There is greater need for innovations to increase the adoption of carbon composites.

The usage of carbon composites is still evolving. Because end-users seek more value for their money, superior quality and increased safety, the composites industry will be forced to deliver the desired output as customers demand shifts. When Lucintel spoke to automotive OEMs about the opportunities related to carbon fiber usage, all responded that they see carbon fiber as one of the most promising weight-saving materials, but they are faced with many challenges in using it. The following are four key challenges that the carbon composites industry need to address to get a bigger piece of future growth and profitability — all of them related to per-part cost.

- **Fiber cost reduction:** Reduction in the price of raw carbon fiber is critical to making CFRP parts competitive with »


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steel and aluminum parts. The high price of carbon fiber restricts potential leverage in many applications. For example, automotive OEMs demand carbon fiber within the range of US$5-US$7/lb; however, the current price is approximately US$8-US$15/lb for automotive applications.

- **Transformative technology:** There is a great emphasis on reducing part fabrication cost via automation, simulation and rapid cycle time. There is a greater need for faster, more mature composites technologies, targeting 1-2 minute cycle times for mass-volume markets. Most current carbon composites part manufacturing processes are slow and take several minutes to make the part. Automation and development of suitable material systems and technologies are required to gain wider acceptance of carbon composites in mass markets.
- **Recycling:** There is a greater need than ever before to address recycling of composite parts if CFRP is to be used in mainstream applications. For example, automakers are reluctant to use composites in a major way until the recycling issue can be addressed, out of concerns driven by government regulations, such as the European Union's automobile end-of-life directives.
- **Repair:** Repairing composites is a big challenge. Until repair can be done efficiently, its wider acceptance in mass-vehicle platforms will be stalled. Auto OEMs explain that for steel and aluminum, they have well-developed repair technologies, but these have not been developed for CFRP parts.

In conclusion, Lucintel predicts that the next big thing for the composites industry will be the automotive industry. To capture future growth and find profit from these challenges, OEMs, Tier 1 suppliers and material suppliers cannot simply turn to their traditional toolbox. They need to review the opportunity and adjust their priorities, deploy the appropriate investments and resources, and develop new skills and technologies to execute these strategic objectives.

If all major players in the industry work together — OEMs, part fabricators, and material suppliers — the future is bright for CFRP. CW

ABOUT THE AUTHOR

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Follow the leader — or maybe not

» In June 2013, I posed the question whether any other automotive OEM would follow BMW's (Munich, Germany) lead in capturing the entire carbon fiber composites supply chain, as the company has done for its *i-Series* and, more recently, its flagship *7-Series*, with the Carbon Core concept. Three years later, the answer seems to be a resounding "no." Based on my observations, replication by additional OEMs doesn't appear to be on the horizon, either. Does this suggest that BMW may have erred in this endeavor?

I don't think so. The drivers for making vehicles lighter have not changed. Because others don't quickly follow, many innovations take a lot of time to proliferate, or to be adopted by competitors. I've spent a lot of time with the folks at BMW the past two years, visited their composites manufacturing lines, and it's clear they have learned much that is difficult to replicate without actually living through the experience.

> The easy explanation for lack of proliferation of carbon composites is the "not invented here" syndrome.

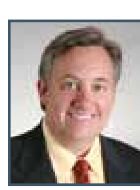
The "intelligent lightweighting," as I have termed the Carbon Core concept indigenous to the *7-Series* platform, certainly arose out of BMW's experience on the *i3* and *i8* platforms. The rumored *i5* vehicle is likely to have more metal and fewer composites than the other *i-Series* vehicles, yet will be both weight- and cost-effective, if produced. BMW is still fine-tuning the balance between composites and metals.

The BMW example is far from unique. Glass-reinforced phenolic disc brake pistons were first introduced in the US market between 1968 and 1970 as a replacement for steel pistons. They managed to gain significant traction in the US during the following two decades, but European OEMs would not embrace the idea. In the mid-1990s, I was calling on European brake systems companies, many with US affiliates that used phenolic, trying to convince them that there was a quarter century of empirical evidence in support of composite pistons, but I kept hearing excuses: "Our speeds are much higher" or "Our mountains are too steep."

Granted, Germany did have, on average, roads with higher speed limits, but the highest paved mountain road in Europe is in Spain at 3,384m/11,102 ft, and phenolic pistons had demonstrated superior performance to steel in the US on descent from Pikes Peak in Colorado, with a top paved elevation of 4,300m/14,110 ft. It wasn't until the late 1990s that General Motors' (Detroit, MI, US) European subsidiary, Opel AG (Rüsselsheim am Main, Germany), began using phenolic pistons, and they continue to gain market share in Europe. It only took about *30 years* for this to happen. Conversely, there are numerous composite components on European vehicles that have never made the transition to US or Japanese platforms.

Aerospace has similar stories. The Airbus (Toulouse, France) A320-200 made its first commercial flight in 1988 with a fully composite empennage. Seven years later, The Boeing Co.'s (Chicago, IL, US) 777 flew with a similar construction. This was relatively quick by comparison to the auto brake piston example. The time span between the first flight of the carbon fiber fuselage on the Boeing 787 and the similar Airbus A350 was only three years and three months. By any account, this is exceptionally fast. However, the first FAA-certified, carbon fiber pressurized fuselage appeared on the Wichita, KS, US-based Beech Aircraft *Starship* in 1989, delivered fully 22 years before the first commercial flight of the 787. While the *Starship* was not a long-term commercial success, the technology has been well proven — and there are a handful of registered aircraft still operated by private owners. For those well-versed in aerospace history, this technology was first demonstrated on LearAvia's (Reno, NV, US) all-composite *LearFan 2100* in 1981, although that aircraft was never certified, due to problems unrelated to the composite components.

The easy explanation for this lack of proliferation is the "not invented here" syndrome, and, to be sure, that plays a big role. Leadership at various companies define materials strategy in different ways, and every engineer needs to be certain that a design will meet required performance parameters. Perhaps an alternate approach to that pursued by BMW can achieve the same result — a number of automotive OEMs have established close relationships with carbon fiber suppliers and Tier 1 molders, each of which will have to make large investments to fulfill volume requirements. Whether this strategy enables each OEM to meet the required emissions or fuel-economy requirements in a *timely* fashion remains to be seen. In aerospace, Bombardier has already taken the leap, using carbon fiber wing structures on its *CSeries* single-aisle aircraft. Will Airbus and Boeing follow? So far, the response by both has been to aggressively price the A320 and 737 to keep Bombardier at bay. But long term? I'm guessing they will follow. Eventually .... CW



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The FAA: Keeping up with aerocomposites evolution

» The Greek philosopher Heraclitus of Ephesus once said, "Change is the only constant." We can see the inherent truth behind this statement when we look at the evolution of materials in aerospace. The *Wright Flyer* was the first successful heavier-than-air powered aircraft. Built in 1903, the *Flyer* had a wooden frame. The straight parts were spruce and the curved parts were ash. The frame was covered with a finely woven cotton cloth and was sealed with canvas paint similar to what mariners of the time used on their sails[1-3]. In the next era of aircraft construction, builders used metallic alloys, which were much stronger than wood, allowing for improved performance. Today, most aircraft are constructed from a combination of metallic and composite materials as performance continues to improve.

The Boeing Co. (Chicago, IL, US) first used fiberglass in its 707 passenger jet in the 1950s, and it comprised roughly 2% of the structure. Since that time, each generation of Boeing aircraft has had an increased percentage of composite materials. Boeing's 787 *Dreamliner* is approximately 50% (by weight) composites[4]. Airbus, Boeing's main competition in the large transport aircraft category, has countered with the A350, which makes extensive use of composites, as well, also roughly 50% by weight. However, because safety is the number one priority of the aerospace industry, materials have evolved gradually over time.

In the late 1970s and early 1980s, NASA, through its Aircraft Energy Efficiency (ACEE) Advanced Composites Structures Program, challenged large-transport manufacturers to use graphite material to redesign existing aircraft components. The program's goal was to develop the necessary data and technology to achieve production commitments to advanced composites. The graphite/epoxy horizontal stabilizers that were developed by Boeing for its 737 as part of this effort were put into commercial service in 1984. They have performed outstandingly, with no service incidents reported[5]. This led to increased confidence in, and acceptance of, composites for primary aircraft structure.

Composite and metallic structures must conform to the same performance-based standard of safety.

The mission of the FAA is to provide the safest, most efficient aerospace system in the world. The FAA develops aviation regulations that set the minimum acceptable levels of safety in aviation. As materials and structures continue to evolve, the FAA constantly must evaluate the adequacy of its regulations, policy and guidance materials. Title 14 of the *Code of Federal Regulations* (*CFR*) contains all of the regulations for aeronautics and space[6]. These regulations are generally performance-based rather than prescriptive, which means both composite and metallic structures have to perform to the same standard of safety.

In addition to certifying the aircraft flying in the United States National Aerospace System (NAS), the FAA is proactively working to ensure the safe transition to composites. The William J. Hughes Technical Center (Atlantic City, NJ, US) is the FAA facility in which engineers research a wide variety of materials, including composites. In 2003, the FAA created the Joint Advanced Materials and Structures (JAMS) Center of Excellence[7], a consortium of universities that conducts research for the FAA in the areas of testing and analysis, bonding and repair, damage tolerance, environmental factors and crashworthiness. The FAA, the aerospace industry and academia work side by side continually to raise the bar for safety.

Tech Center test fleet

These FAA flight test aircraft, located at the William J. Hughes Technical Center, function as an R&D testbed and are used for the purpose of evaluating navigational systems, communications systems and flight loads. Source | FAA

The FAA also takes a proactive approach towards composites through the *Composite Materials Handbook-17* (*CMH-17*), which provides information and guidance necessary to design and fabricate end items from composite materials. Its primary purpose is the standardization of engineering data development methodologies related to testing, data reduction and reporting of property data for current and emerging composite materials[8]. Experts from all over the world meet each year to develop content for the *Handbook*, which is used by the industry when constructing composite parts for aircraft.

The FAA also provides guidance directly to industry through Advisory Circulars (ACs). *AC 20-107B* sets forth an acceptable means for manufacturers to comply with 14 *CFR* regarding airworthiness type certification requirements for aircraft structures that involve fiber-reinforced materials. It also includes information on material and process control, manufacturing, structural bonding, environmental considerations, protection of structure, generating design values, structural details, proof of structure for static strength and fatigue and damage tolerance, as well as repair, inspection, crashworthiness, fire protection, flammability, thermal issues and lightning protection[9]. This AC was most recently updated in 2009. However, because the industry is constantly evolving, the next revision is not too far down the road. »

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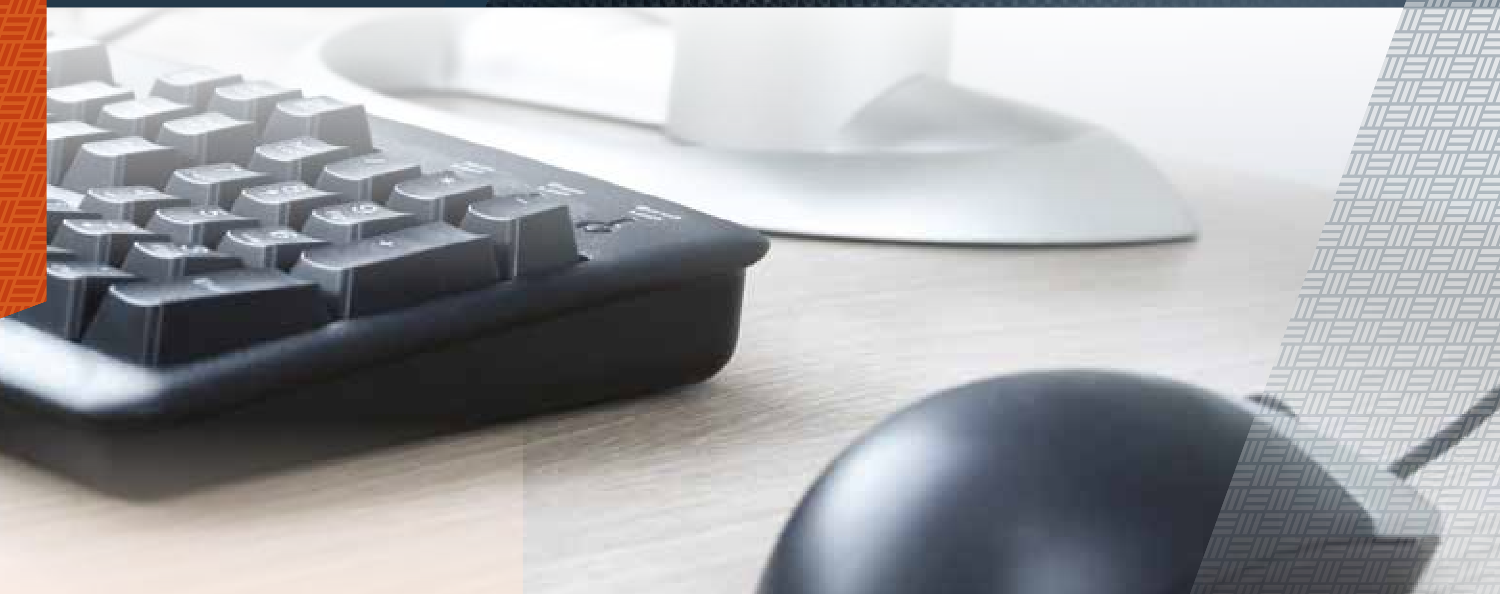

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Another high priority for the FAA is educating the composites workforce, which is essential to continued certification efficiency and operational safety. Success here depends on FAA workforce knowledge of composites technologies. With this in mind, the FAA created Composite Manufacturing Technology (CMfgT), Composites Structures Technology (CSET) and Composites Maintenance Technology (CMT) courses for its aviation safety inspectors. Courses are offered by the National Institute for Aviation Research (NIAR) at Wichita State University[10]. FAA composites educational initiatives also include developing a course and proficiency specimens for airline inspectors and updating 14 *CFR* Part 147 composites training requirements for aviation maintenance schools.

NASA also is very active in composites research, and has created the Advanced Composites Consortium to develop technologies and methodologies that will enable more efficient design and implementation of composites in aerospace[11]. The FAA is continuously coordinating with NASA and other government agencies to foster these developments.

The advantages of building aircraft with composites — high specific strength, superior fatigue properties, damage tolerance and the absence of corrosion — continue to make composites an attractive option for aircraft designers. Along with the industry, the FAA is working hard to ensure that composite aircraft continue to soar safely through our skies. CW

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- Design and Engineering of Structural Applications Based on Thermoplastic Composites
- Coupled Heating-Forming Simulation of the Thermoforming of Thermoplastic Composites
- QSP®: How to Produce a Netshape Thermoplastic Composite Part in One Minute
- Automotive Crashbeam from UD Tapes by Tailored Blanks Production and its Optimisation
- Influence of the Cathodic Dip Painting Process on the Mechanical Properties of Fibre-Reinforced Thermoplastic Composites

Session B: Aerospace I

- Overmoulding – An Integrated Design Approach for Dimensional Accuracy and Strength of Structural Parts
- Efficient Laser Cutting of High-Performance Thermoplastic Composites
- Hybrid Textiles – The Novel Way of Forming High-Performance Thermoplastic Composites for Primary Structure
- Sequentially Coupled Material Flow and Multi-Scale Stress Analysis of Discontinous Long-Fiber Composite Helicopter Fairing Rib
- In-Situ Strain Monitoring-Based Simulation of Residual Stress/ Strain Due to Skin-Core Effect in Thick CF/PPS Laminates

Session C: Eco-Efficient Processes and Applications

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- A New Generation of Aesthetic Composites Based on Styrenic Polymers
- New Reactive Resins for Thermoplastic RTM & Pultrusion

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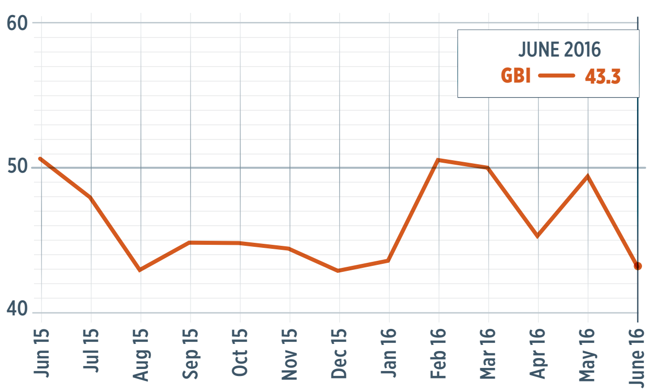
June 2016 — 43.3

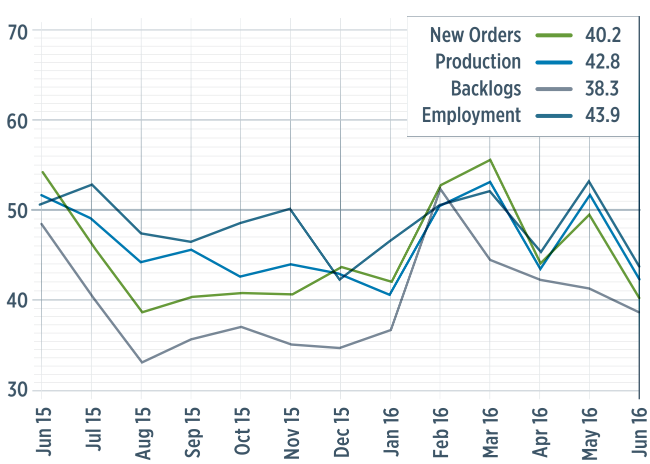
Compared with one year ago, future capital spending plans are up by 43%.

» With a reading of 43.3, the most recent Gardner Business Index showed that the US composites industry had contracted at a significantly faster rate in the month of June than it had at any refernce point previously in 2016. The decline brought the Index back to the general level recorded in the second half of 2015.

New orders contracted for the third month in a row. The new orders subindex had, by the end of June, fallen sharply since March. The production index contracted for the second time in three months as its subindex fell to its lowest level since January of this year. The backlogs index contracted as well, and did so at an accelerating rate for the fourth straight month. The employment figure contracted, too, for the second time in three months, and its subindex fell to its second lowest level since the GBI Composites survey was initiated in December 2011. Despite the moderation in the value of the US dollar, US exports continued to contract in June. Supplier deliveries lengthened for the fifth time in the first half of 2016.

A GBI reading of >50.0 indicates expansion; values <50.0 indicate contraction.



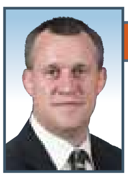


The materials prices subindex, as June closed out, had increased dramatically in 2016. Although the rate of increase did slow down in June, the subindex was at its second highest level in the previous 18 months. Prices received decreased for the ninth month in a row. The future business expectations subindex, in June, was fairly flat again, as it had been in four of the preceding five months.

For the most part, US composites manufacturers felt the effects of industry contraction. Plants with more than 250 employees contracted for the seventh straight month. Their subindex fell to its lowest level since the survey began. Facilities with 100-249 employees contracted in June after having posted growth in five of the previous six months. Companies with 50-99 employees, however, were the exception: As a group, they posted expansion as June closed out — the third posting of growth during the preceding five months. Facilities with 20-49 employees contracted in June after growing in three of the previous four months. Plants with fewer than 20 employees contracted for a fourth month in a row.

The aerospace industry contracted, but it was its first time under 50.0 since January 2016. Although the aerospace industry had performed well for composites fabricators from January through May, the automotive industry, through June, had posted contraction for seven consecutive months. This mirrored motor vehicle and parts consumer spending, which had contracted five of the previous six months.

Future capital spending plans, in June, fell to their lowest level of 2016. But, compared with one year earlier, future capital spending plans actually were up by 43%. Month-over-month, they had increased, as June closed out, in three of the previous four months. The annual rate of change, in June, had contracted at a decelerating rate since February 2016, which as *CW* went to press, was a positive sign for the US composites industry. CW



ABOUT THE AUTHOR

Steve Kline, Jr. is the director of market intelligence for Gardner Business Media Inc. (Cincinnati, OH, US), the publisher of *CompositesWorld* magazine. He began his career as a writing editor for another of the company's magazines before moving into his current role. Kline holds a BS in civil engineering from Vanderbilt University and an MBA from the University of Cincinnati.
skline2@gardnerweb.com

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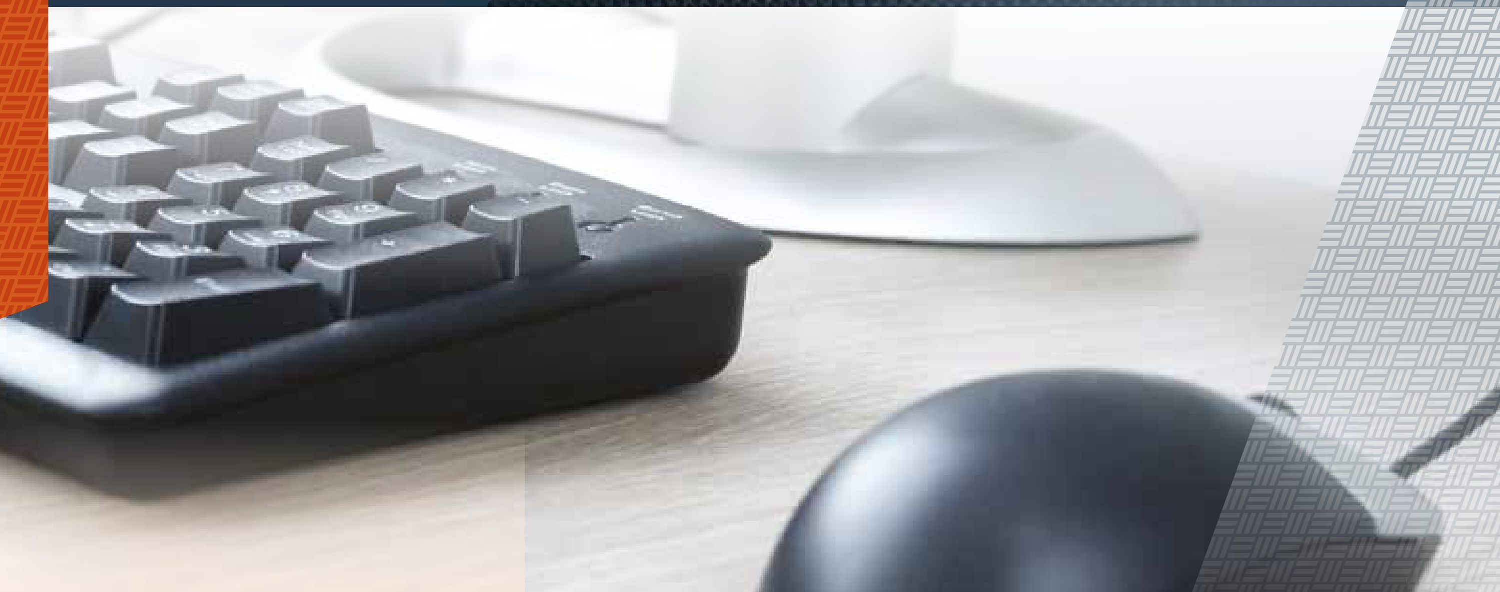

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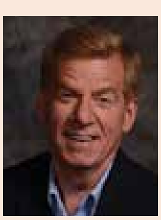

STEVE WILSON
Director of Global Business Development—Plastics & Rubber
Cold Jet, LLC

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Another ultralow-density SMC surfaces, a new "longest" in wind turbine blades, and thermoplastic RTM moves to market-readiness thanks to in-mold polymerization.

AUTOMOTIVE

Ashland unveils SMC with specific gravity of 1.2, aims for 1.0

Prompted by customer demand for a tough, low-density, E-coat-capable, cost-effective SMC, Ashland Performance Materials (Columbus, OH, US) has developed Arotran 771, the company's newest sheet molding compound (SMC), designed specifically for use in automotive applications. Arotran 771. It offers a specific gravity of 1.2, and represents a substantial increase in Ashland SMC performance, reportedly comparable to that of the first SMC to test as low as 1.2, TCA Ultra Lite, introduced in 2015 by Continental Structural Plastics (CSP, Auburn Hills, MI, US; see short.compositesworld.com/CSP-LDSMC). Specific gravity, a measure of a material's density, impacts its weight, a critical concern for automakers. Michael J. Sumner, Ashland's group leader — gel coat, SMC, marine resin, says the company is trialing Arotran 771 with several customers involved in the automotive supply chain.

In the meantime, Ashland isn't standing pat. Sumner reports that the company is already working on chemistries designed to push SMC specific gravity down to 1.1 and, eventually, to 1.0. In terms of weight and cost savings for automakers, that's the magic number. "If we can get to 1.0," Sumner asserts, "we can effectively compete with aluminum." And those products could come on the market relatively soon.

At SPE's Thermoset Topcon conference (April 19-20), Sumner walked attendees through the just-announced SMC's development history, with particular emphasis on the evaluation of resin performance. Ashland had looked at various combinations of vinyl ester and unsaturated polyester resin (UPR), testing for finished part surface quality, mechanical performance, T_g and E-coat tolerance.


Source | Ashland

Initial tests of surface quality, as measured by advanced laser surface analyzer (ALSA), showed that a 50/50 blend of vinyl ester and UPR was optimal, with an ALSA value of 64. Ashland added reactive toughener (at 5 wt%) to the mix and got very good mechanical values: tensile strength of 85 MPa, tensile modulus of 8,600 MPa, flexural strength of 182 MPa, flexural modulus of 8,200 MPa and elongation of 1.41%. Drop dart impact resistance is 3.1J.

Further testing, Sumner says, revealed that the selection of initiator system and mold temperature can influence part quality. Ashland conducted a series of tests, combining different initiators with mold temperatures of 121°C or 150°C, and then evaluating finished samples for surface quality and mechanical properties. The best-performing combination included the reactive toughener and a mold temperature in the 121-150°C range.

To assess E-coat performance, Sumner says Ashland fabricated several SMC panels to a Ford Motor Co. (Dearborn, MI, US) specification and ran them through the Ford E-coat test protocol, involving exposure to 38°C and 100% humidity for 10 days, followed by short-term exposure to 200°C heat. The panels showed absorption of 2.25% with no blistering — the latter is a requirement for test success.

BIZ BRIEF

Dilutec (Senador Canedo and Piracicaba, Brazil), is a leading South American manufacturer of gel coat and thinner in Brazil, and a distributor of composites molding equipment. An exclusive agent of **BÜFAtec Spain** (Barcelona) in Brazil, Dilutec is expanding its distribution network in 2016. Currently, the company relies on four distributors in Brazil and one in Uruguay. Marcos Pannellini, commercial manager of Dilutec, says the intention is to accredit at least four more distributors by year's end, in the states of São Paulo and Rio Grande do Sul, as well as partners that can sell its products elsewhere in South America. In Brazil, Dilutec's network currently consists of Assunção (Pernambuco and Paraíba), Bahia Fibra (Bahia), Mega Fibra (Rio de Janeiro) and Oticrel (Ceará) – Dimena, located in Montevideo (Uruguay), completes the list. In the Brazilian Central-West region, retail is covered by Dilutec, which has a unit located in Senador Canedo, in the metropolitan area of Goiânia. In 2015, distribution accounted for 20% of Dilutec's revenues, a share that should increase to 35% with the additional distributors.

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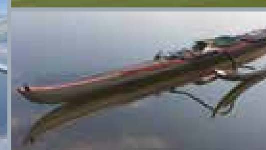

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ENERGY

Adwen and LM Wind Power produce the world's longest wind turbine blade

Adwen (Bremerhaven, Germany), a 50/50 joint-venture between wind turbine OEMs AREVA (Paris Le Défense, France) and Gamesa (Zamudio, Spain) dedicated to offshore wind, has partnered with long-time blade manufacturer LM Wind Power (Kolding, Denmark) to produce the longest turbine blade in the world.

The 88.4m-long blade has been specifically designed for Adwen's AD 8-180 wind turbine, which is rated at 8 MW of nominal electric power-generating capacity and, not surprisingly, also has the largest rotor diameter, at 180m and, as a result, the highest annual energy production (AEP) of all currently fielded wind turbines.

The first of the turbine's huge blades has been manufactured at LM Wind Power's factory in Lunderskov, Denmark, and will be transported to a facility in Aalborg, where it will enter a rigorous testing regime as part of Adwen's extensive product-validation plan. The engineering teams at both companies have worked in concert for months to design and integrate the blade's composite components.

"When you are building the largest wind turbine in the world," comments Luis Álvarez, Adwen's general manager, "almost everything you do is an unprecedented challenge. We are going where no one else has ever gone before, pushing all the known frontiers in the industry. Having developed and integrated together with LM Wind Power the first unit of the longest blade ever and being able to start testing is a key step forward in the development of our AD 8-180 and proves that Adwen is at the forefront of the industry."

Learn more about Adwen at **www.adwenoffshore.com**

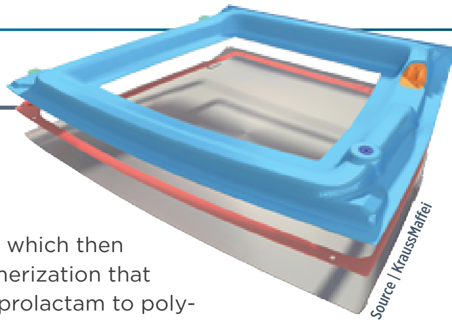
AUTOMOTIVE

Thermoplastic RTM comes to market via in-mold polymerization

KraussMaffei Technologies GmbH (Munich, Germany) reports that it will introduce this fall its T-RTM thermoplastic resin transfer molding process, which will produce near-net shape fiber-reinforced polyamide 6 parts under high-rate series production conditions, based on the inherent advantages of in-mold polymerization of caprolactam.

At the K 2016 exhibition, in Düsseldorf, Germany, KraussMaffei will use a T-RTM system to demonstrate production of a thermoplastic composite frame for the roof shell of the *Roding Roadster R1* sports car (Roding Automobile GmbH, Roding, Germany). A structural component with metallic inlays, the frame will be molded under series-production conditions in the KraussMaffei exhibition stand several times a day.

The T-RTM process uses a closed press mold and a continuous fiber preform. KraussMaffei notes that it will use a "multi-preform" concept that minimizes fiber waste and enables a tailored fiber architecture. But rather than injecting relatively high-viscosity polyamide 6 resin into the mold cavity, the monomer caprolactam, from which PA6 is made, will be injected, and will be mixed at injection with an



activator/catalyst, which then triggers the polymerization that transforms the caprolactam to polyamide 6. KraussMaffei says the low viscosity of caprolactam — similar to that of water — will enable the matrix material to easily and thoroughly penetrate the fiber layers *prior to polymerization*, even at low internal mold pressures. For the application demonstrated at the exhibition, a clamping force of approximately 350 MT will be used. In addition, the high flow capacity of the process will permit a reduction in the minimum-allowable part wall thickness and will allow a part's fiber volume fraction to be increased to about 60%. The Roding part also will feature a thermoplastic tear-off edge that is reportedly easily removed, post-mold.

According to Erich Fries, head of the Composites/Surfaces business unit at KraussMaffei, "The production process on the KraussMaffei K 2016 exhibition booth will last about 2 minutes. The system is intended for high-volume projects and is designed for multiple-shift operations."

CW will be at K 2016 and will report again with additional information about this process.

Read more online about in-mold polymerization | short.compositesworld.com/InSituPoly

CW / MONTH IN REVIEW

Notes on newsworthy events recently covered on the *CW* Web site. For more information about an item, key its link into your browser. Up-to-the-minute news | www.compositesworld.com/news/list

New report on composites recycling
Recovery processes, re-use and application, environmental impacts, applications for dry fibers and legislation are all covered in the document.
07/14/16 | short.compositesworld.com/RecycleRpt

AGC AeroComposites acquires North Coast Composites
The deal includes North Coast Composites Inc. and North Coast Tool and Mold Corp., both based in Cleveland, OH, US.
07/14/16 | short.compositesworld.com/AGCAeroNCC

Boeing, Airbus optimistic about commercial aircraft demand
Over the next 20 years, Boeing projects demand for 39,620 new airplanes; Airbus predicts demand for more than 33,000 new aircraft.
07/11/16 | short.compositesworld.com/Demand2026

Museum installation features composites structure
The Victoria and Albert Museum has unveiled a composite-intensive architectural installation developed by a team from the University of Stuttgart.
07/11/16 | short.compositesworld.com/MuseumComp

Transport Canada awards type certification to Bombardier CS300
Delivery of the first composites-intensive *CS300* airliner to airBaltic (Latvia) is scheduled for the fourth quarter of 2016.
07/11/16 | short.compositesworld.com/CS300Cert

Solvay-Mubadala joint venture to provide prepreg for 777X
The joint venture will manufacture carbon fiber prepreg for the plane's empennage and floor beams at a new facility in Al Ain, UAE, to be operational by 2021.
07/11/16 | short.compositesworld.com/777Xprepreg

Honda Aircraft receives FAA certification
The Production Certificate grants the airframer the authorization to produce, flight test and issue airworthiness certificates for its *HondaJet* for customer deliveries.
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Huntsman, Acciona collaborate on all-composite lighthouse
The first-ever all-composite lighthouse structure has been installed and is operational at the port of Valencia in Spain.
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PlastiComp opens long-fiber composite thermoplastic lab
In addition to development of new products, the lab will also provide contract research and development services for industry partners.
07/06/16 | short.compositesworld.com/PlastiLab

NASA successfully tests rocket booster
This was the last full-scale test for the booster before SLS's first uncrewed test flight with NASA's *Orion* spacecraft in late 2018.
07/05/16 | short.compositesworld.com/NASAboost

BIZ BRIEF

Henkel's (Dusseldorf, Germany) recently opened Composite Lab in Heidelberg is intended to enable Automotive OEMs and Tier-1s to work with Henkel resin chemists, and choose from Henkel's diverse portfolio, which includes composite matrix resins, composite adhesives and more, as they develop and test composite parts and determine what process conditions will best make their product design concepts market-ready. Henkel says its customers seek cost-effective processes suitable for production of more than 10,000 parts per year but also want custom-formulated, fast-curing resins for use in short production cycles. This magnifies the importance of having reliable partners with in-house test capabilities that can simulate series-production conditions. Henkel's Lab is equipped to enable customers to do trials, using high-pressure resin transfer molding (HP-RTM) on a 380-ton press, and also features injection equipment for polyurethanes and epoxy materials.

Fine-tuning fiberglass: Smart fiber sizing

Some insights into those proprietary chemistries that can customize performance at the fiber/resin interface.

By Donna Dawson / Senior Writer Emeritus

» In the composites industry, fiber is a significant topic of conversation. Fiber *sizing* rarely gets a mention. It is difficult, however, to overstate sizing's importance. Without it, the fiber could quickly begin to fray during handling and processing (see Fig. 1, this page), and would resist bonding with the matrix resin. In addition, sizing is credited with improving mechanical properties, such as tensile strength and resistance to impact, fatigue and chemicals, and promoting thermal stability and hydrolytic stability and more.

Fig. 1 Proprietary, but key to performance

A variety of fiberglass products (above, right) are sized for composites production. The sizing protects fiber from fraying/breaking during handling at initial manufacture (above left) and during downstream processing, such as weaving, and it ensures adhesion at the critical fiber/resin interface.

Source | Owens Corning

The biggest sizing consumers are glass fiber manufacturers. Worldwide annual production of fiberglass composite materials is nearly 9.07 million MT, and fiberglass accounts for some 95% of all fiber reinforcements processed by the composites industry, according to Prof. James L. Thomason, University of Strathclyde (Glasgow, Scotland, UK).

One of the largest glass fiber manufacturers in the world is PPG Industries (Shelby, NC, US). It uses silica (SiO_2) sand and other selected raw materials co-melted in a 1450°C furnace and directed through forming bushings that shape glass fibers (see Learn More, p. 30). The fiber sizing is applied immediately after the filament exits the bushing. "We're applying our coating that's about 100 nm thick to a cylindrical surface that's around 10-20µ in diameter,

Fig. 2 Distinctive and proprietary formulations

Chemists mix sizing in a cleanroom environment. Sizing chemistry is among the most highly guarded of trade secrets, in part because it is one of the factors that most distinguishes one fiber product from another. Source | Michelman

Fig. 3 Sizings tailored to the task at hand

Car interior instrument panel support beams, arm rest frames and center console supports are among the many parts made from fiberglass/polypropylene with sizings tailored, customized and optimized in a way appropriate to the end-use application. Source | Michelman / Photo | Thinkstock (Photographer / Maudib)

and is moving at speeds approaching 100 mph [160 kph]," explains James C. Watson, associate director, fiberglass science and technology, for PPG Industries, "and we're doing it 24 hours a day, 7 days a week, 365 days a year. We never stop."

"It's a little bit of a challenge," he quips, pointing out that after it is applied, the sizing also must remain on the fiber and perform its functions throughout all subsequent phases of the glass manufacturing process, the customer's part manufacturing process and the finished part's lifecycle. He adds that in terms of the total composite, sizing can make up as little as 0.2-0.3% of the final product, yet it has an "amazing impact on productivity and part performance."

What is sizing?

Sizing describes, respectively, the coating itself *and* the coating process. *Whittington's Dictionary of Plastics* (Third ed., CRC Press, 1993) defines the latter as "applying a material to a surface to fill pores to smooth it and reduce absorption of a subsequently applied adhesive or coating; or to otherwise modify the surface."

Today, sizing chemists (see Fig. 2, above) primarily aim first to protect the fiber by reducing friction during processing and to prevent fiber breakage during part manufacturing. Second, they provide a compatible interface between the fiber and the matrix resin in the composite part. Specifically, sizing enables *transfer of stress* across the fiber/resin interface.

"The sizing controls the interface between the glass and the resin and, therefore, optimization of the sizing chemistry gives you the best interfacial performance between the glass and the resin. Good interfacial performance leads to improved mechanical performance and to better processability as well," explains Christopher Skinner, director of products for the strategic marketing group at glass fiber manufacturer Owens Corning (OC, Toledo, OH, US).

Glass fiber sizing primarily comprises a *film former*, typically chemically similar to the intended matrix resin, and a *coupling agent*, almost always an organic silane base in a complex mixture of chemistries that gives the *inorganic* glass fiber the ability to bond well with the *organic* resin matrix. The silane coupling agent acts as a primer that enables the film former to attach to the fiber and also adhere to the polymer matrix.

Watson points out that silanes are the glass fiber sizings chemists' workhorses. "But as we move forward to higher temperature, higher durability, longer life term, better fatigue performance and other improved performance, we must ask ourselves if there are better organic silane molecules that can be used to bring those properties to bear — even though they are invariably more expensive."

Differentiation + optimization

Today, there are no general-purpose sizings — no one-size-fits-all formulae, says Steve Bassetti, global marketing manager, fibers and composites, for fiber sizing supplier Michelman (Cincinnati, Ohio, US). "Several key variables need to be understood in the sizing selection process," he says, expanding on his theme: "Clearly, [one is] the *resin* that the fiber is going to be put into, be it polyester, epoxy, polypropylene, nylon, PAEK or other."

Fausto Pellegrini, key account manager and team leader for Aliancys (formerly DSM Composites, Schaffhausen, Switzerland) »

Fig. 4 Optimizing sizings for fiber-reinforced thermoplastics

This automotive front-end module, for housing a car's radiator and other components, is made using LFT processing, from fiberglass with Michelman's (Cincinnati, OH, US) Hydrosize sizing customized for a polypropylene matrix. Source | Michelman

says, for example, that Aliancys is working on sizings for excellent wettability and compatibility with newer *styrene-free* resins. "Often," he explains, "sizing chemistries for styrene-containing thermosets do not perform well when used with new styrene-free resin that is based on methacrylate solvents and derivatives."

Second, says Bassetti, is the intended *process*, which includes whether the sizing is for chopped or continuous fiber and the forming method, such as compression molded sheet molding compound (SMC) or filament winding.

PPG's Watson says, "An important trend in the past 5 or 10 years has been a great broadening in different kinds of glass compositions, in addition to traditional E-glass, to more corrosion-resistant ECR glass and to high-modulus glasses." Sizing products, therefore, also are increasingly driven by changes in glass composition and accompanying changes in the fiber surface to make sizing compatible with corrosion-resistant, low-boron or boron-free glass, for example, or high-modulus glasses for wind turbine blades, he says.

Aliancys, says Pellegrini, is developing sizings for specific inline wetting processes, such as pultrusion and filament winding, aimed at reducing part production time and process energy consumption.

Last but not least, the chemist must consider *part performance* and the *environment* where the part will be installed — an automotive interior, underhood or fuel-system component, an electronic laptop component, a wind blade or one of myriad other market applications. That includes the challenge to sizing chemists of *part* size. Aliancys' Pellegrini says that sizings based on low-molecular-weight epoxy chemistry have been successfully used for years in wind turbine blades and other direct roving applications. Wind blades are getting longer, however, to increase wind turbine power output, emphasizing the need for durability, stiffness and fatigue resistance in fiberglass blades.

Skinner notes that blade manufacturers invest an "incredible amount of money in tooling" for, say, a 75m long blade. And then "they put more than 40 tons of glass into a mold and infuse it with resin." With so much capital in fixed assets, the ability to make parts quickly is critical. "So the ability of sizing chemistry to respond to the increasing *scale* of applications is a key factor in sizing innovations," says Skinner. Here the fiber/resin bond is key. "So we're driving interfacial science to drive up the performance of our products."

Fig. 5 Experimenting with SiO_2 as an additive

Tests conducted by researchers at Evonik (Essen, Germany) indicate that the performance of wind turbine blades could be significantly increased by adding nanosilica to the glass fiber sizing formula.

Source | Evonik Industries

The industry is asking for fiber performance improvements that will demand specific sizings, tailored, customized and optimized in a way appropriate to the end-use application, Bassetti explains, noting that for Michelman's line of sizing products, including its registered flagship product, *Hydrosize*, the fiber interface is becoming more critical as advances in resin and fiber technology reach maturity. "Today's research is targeted at specific applications," Bassetti points out, offering as examples, a polypropylene supplier that might be looking for low VOCs in automotive interiors (see Fig. 3, p. 27), or a nylon supplier that might need greater hydrolytic resistance or better glycol resistance.

Bassetti sums up the trend in a single word: *Specialization*.

Competition + regulation

Pellegrini frames the specialization trend in terms of global market pressures. Demand for glass fiber will continue to be high, but strong price competition from fiber suppliers in Asia has been a factor in challenging established glass fiber producers to focus on reducing costs by improving their efficiency and productivity.

"Composites is typically seeing 4-5% annual growth," agrees OC's Skinner, based on well-documented substitution of composites for legacy wood and metal for the purpose of weight reduction and/or corrosion prevention, but he also notes what he calls *specialty features* — specific durability or aesthetic, acoustic or weather-resistance requirements prized for building construction materials.

Skinner adds that the European Union's REACH legislation, adopted to enhance human and environmental protection from risks posed by certain chemicals, also is driving sizing developments. It's not just about low VOCs in sizing, but also about the highly specialized chemicals that are used in sizing to produce specific effects. "The REACH legislation has a hand in specifying approved chemicals," Skinner points out. So a big challenge for sizing chemists is to achieve the desired effect yet comply with the legislative environment. In other words, "How do we continue to innovate *and* respond to corporate social responsibility?"

Pellegrini notes that among Aliancys' R&D efforts in VOC-free sizing formulations for reduced environmental impact, are sizing chemistries that meet new European regulations for parts in contact with food.

"We are seeing more and more demand coming from the automotive industry," notes Gilles LeMoigne, Michelman's global industry manager, fibers and composites, as automakers turn to composites for fuel economy, and to alternative fuels — which are typically stored in composite pressure tanks — for cutting CO_2 emissions. Sizing for structural SMC for lightweight body panels also is on the table for its chemists. "Michelman aims for sizing designs that will help the auto industry meet the latest regulations for composites manufacture." These include such goals as low or no volatile organic compounds (VOCs) in its sizing, and sizing that will meet specific targets for impact resistance or tensile strength.

Sizing for glass/thermoplastics

On the cutting edge of the custom-designed sizings trend are thermoplastic composites. Bassetti insists that any composite, and a thermoplastic in particular, is under-optimized when a general-purpose sizing is selected. "Again, our business is to specialize the interface and improve the composite performance," he says.

But he cautions that the latest in thermoplastic sizing is still being developed and validated, and good products are not necessarily commercially available yet. In this arena, as well as in thermosets, he reminds us Michelman is working toward *specific* sizing targeted at different applications: Long-fiber thermoplastics (LFT) using polyamides (nylon) and polyolefins — polypropylene (PP) primarily — aimed, for example, at automotive seat backs, load floors, door modules and other interior parts.

Skinner sees a general trend in resin selection from polyester and vinyl ester towards polyurethane (PUR) — a family of polymers with widely ranging properties that may be thermosetting or thermoplastic. "I expect the ability to effectively interact with the PUR matrix is going to become more important in the future," Skinner says. »

A real sizings "hot spot" — figuratively and literally — is automotive underhood applications, where high temperatures and corrosive liquids, such as ethylene glycol (in anti-freeze), and other hot fluids "bring stringent requirements to the design of fiberglass," says PPG's Watson. "The sizing design can result in orders of magnitude improvement in performance, particularly for high temperature and hydrolysis." The best resins for this extreme environment are typically thermoplastic. The workhorses here are nylon (polyamide), PP and thermoplastic varieties of polyester, with limited volume in the polyetheretherketone (PEEK), polyphenylene sulfide (PPS) and polyaryletherketone (PAEK) resins.

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

Read more online about "The making of glass fiber" | short.compositesworld.com/GlassFiber

Read *CW's* online sidebar to this feature article, title "Sizing for carbon fibers" | short.compositesworld.com/CFSizing

Read more about sizing components in *Glass Fibre Sizing: A review of size formulation patents,* Prof. James L. Thomason's analysis of glass fiber sizings based on a review of patents on the technology. University of Strathclyde (Glasgow, Scotland, UK), 2015.

Emerging technologies also will demand customized and improved sizings for best interface functions, Bassetti adds. For example, new ways to use continuous fiber or higher aspect ratios to build additional strength into the composite — processes that require thermoplastic prepregs or organo sheets (strong, lightweight continuous fiber-reinforced thermoplastic structural components) and thermoplastic resin transfer molding (RTM) — are creating new opportunities to optimize the sizing and fiber/matrix interface, Bassetti says. Michelman is actively working on sizing upgrades to fulfill the requirements of these advancements (see, for example, Fig. 4, p. 28).

The latest in sizing technology

Silanes and other sizing components, such as dispersants and emulsifiers, are provided by several divisions at chemical manufacturer Evonik (Essen, Germany). Evonik dedicates a portion of its research to new sizing systems and ingredients. The components that most distinguish one fiber manufacturer's product from comparable fibers produced by another, sizings are highly proprietary (see Learn More). "Fiber sizing is one of the big secrets of fiber manufacturers," says Stephan Sprenger, the senior market development manager for composites and lightweight construction with Evonik's Business Line Interface & Performance group. So it was a notable exception when Sprenger revealed to *CW* that his team is working on the improvements possible when nanosilica (SiO_2) particles are added to sizing in quantities of <1 wt/%.

"When cyclic forces are applied to a fiber-reinforced composite or a sudden impact occurs, microcracks can form within the resin matrix, and over time, the crack propagates through the matrix and along the fiber," Sprenger says. Testing concluded that toughness and fatigue performance of a glass or carbon fiber composite could be *significantly improved* by adding "small levels of an aqueous emulsion of an epoxy resin containing nanosilica to the sizing," Sprenger says.

A 30-40% increase in fatigue performance was achieved in tests with continuous glass fibers and continuous carbon fibers in unidirectional fiber-reinforced epoxy. Sprenger points out that this would be a significant increase in performance of rotor blades for wind energy conversion, for example (see Fig. 5, p. 28). (For more on carbon fiber sizing, see Learn More.)

Called Nanopox, the aqueous emulsion as a sizing ingredient has been tested with epoxy resin matrices, and Sprenger and his team are researching its use with unsaturated polyester and vinyl ester resin matrices. Sprenger considers Nanopox a real breakthrough for sizing manufacturers, at a small additional cost. Further, it is considered viable with any thermoset but, Sprenger says, perhaps not thermoplastic resins.

The same nanosilica particles also can be used to modify the matrix resin, which could achieve even bigger improvements in parts such as automotive composite leaf springs. But he adds the caveat that "modifying the matrix comes with a price, and it might correspondingly affect speed of the manufacturing process." Sprenger emphasizes that adding it to the fiber sizing is a very cost-efficient way to improve composite performance in cost-critical applications such as wind turbine rotor blades or mass-produced automotive parts.

Right sizing for success

For many years, as composites fought for a foothold in automotive, aircraft, construction, piping and other markets that were quite comfortable at the time with concrete, wood or metal, sizing played a key if often unheralded role in the successful substitution of fiber-reinforced polymers for legacy materials. But even in the most successful cases, designers, manufacturers and end-users want far more than a substitute. They want fiber-reinforced polymers with ever greater strength, toughness and endurance than legacy materials. And they want faster productivity. All at a lower cost.

Can fiber manufacturers, sizing chemists and formulators really achieve the upgrades in performance and productivity that their customers demand? They are well aware of the need, and they are certainly suiting up for the challenge. Sizing and fiber manufacturers are coordinating with their customers to hear what they want. And they are taking that information back to their scientists, who are focusing their chemistry on fine-tuning sizing formulations to make specialization a reality, developing the specifically tailored, customized and optimized sizings to satisfy industry demands. CW

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Converting the structural chassis to composites

Germany's largest producer of GRP leaf springs for cars and trucks broadens its product range to CFRP stabilizer bars, which cut weight 50% vs. steel.

By Ginger Gardiner / Senior Editor

» IFA Rotorion (Haldensleben, Germany) ranks among the world's largest manufacturers of driveshafts. Founded in Haldensleben in 2005, its subsidiary, IFC Composite GmbH, now renamed IFA Composite, established a pedigree in a subset of the parent's driveshaft specialty. Using high-strength, lightweight, fiber-reinforced composites instead of steel enabled IFA to integrate additional functions and reduce weight and part count. Three-piece driveshafts could shrink to two pieces, and two-piece driveshafts became single units.

The company uses filament winding, which enables efficient production of high-quality hollow parts and tubes in high volumes. Strands of dry carbon or glass fibers are wound around a reusable cylindrical or conical rotating core and then impregnated with resin. Thermoset or thermoplastic matrices can be employed, as well as prepreg tapes. With an estimated market of up to 300,000 composite tubes among Germany's auto manufacturers alone, automation is now a must (see Fig. 1, p. 33). "The use of wound fiber composite materials in automotive is growing," says Christian Schulz, the company's head of composite structural parts at sister firm IFA Technology GmbH, which develops carbon composite parts. IFA Rotorion

Successful segue into suspension

After successfully supplying front and rear CFRP stabilizer bars for Volkswagen's *XL1*, the automaker's 1-liter sportscar showpiece, IFA Composite has developed additional structural chassis components that are now production-ready.

Source | Volkswagen AG (main photo) / IFA Technology GmbH (inset, lower left)

Fig. 1 Automated filament winding production line

Automated production lines have helped IFA Composite deliver more than 1.3 million glass fiber composite leaf springs with zero defects.

Source | IFA Composite GmbH

Fig. 2 IFA Composite production process

IFA Composite developed a streamlined production process that can be automated and scaled for high volumes: a) preforming, b) press-molding and c) CNC-machining. Source | IFA Technology GmbH

CEO Felix von Nathusius adds, "Cost-effective, large-series, lightweight parts will massively influence the future of vehicle design."

Segue into suspension

IFA Composite also makes glass fiber-reinforced composite leaf springs. It began series production in 2006, making springs for the Mercedes-Benz *Sprinter* van, one of the most successful light commercial motor vehicles worldwide. IFA also produces composite leaf springs for Volkswagen and American Dodge. Most recently, the company has replaced steel in the leaf springs of heavy trucks of up to 40-ton capacity, saving as much as 400 kg in truck empty weight. This either reduces fuel consumption or is exchanged for increased load capacity (see Learn More). As one of Germany's largest composite leaf spring manufacturers, IFA has produced more than 1.3 million composite leaf springs, to date, with a Six Sigma quality measure of zero defects per million parts.

More recently, sister-firm IFA Technology developed and built the world's first carbon fiber-reinforced plastic (CFRP) stabilizer bars in a production car, for the Volkswagen AG (Wolfsburg, Germany) *XL1*. The success of this metal-to-composite conversion has created a fourth strategic business for IFA Composite.

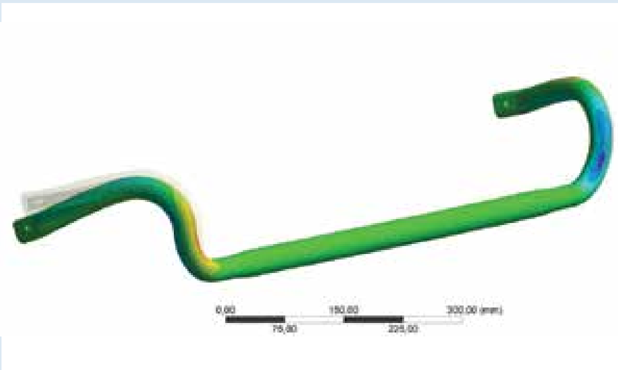
Stabilizer bar form and function

Automotive stabilizer bars, traditionally formed from steel, are a key component in many automobile suspension systems. Also called anti-roll bars, anti-sway bars or sway bars, they are used to reduce the body roll of a vehicle during fast cornering or when a wheel encounters irregularities on the road surface. Stabilizer bars also define a car's oversteer or understeer characteristic — that is, »

Fig. 3 In-house prepregging capability a plus

Given IFA's long history of making glass fiber prepreg in-house on prototype and (pictured here) full-scale production lines supplied by Santex AG (Tobel, Switzerland), its experience and internal process control of carbon fiber/epoxy prepreg fabrication helps ensure superior laminate consolidation in its CFRP stabilizer bars and other suspension parts.

Source | IFA Composite GmbH



1 IFA Composite uses ANSYS software to exploit the significant design freedom that composites enable during the CAD and FEA processes.
Source | IFA Composite GmbH

2 Carbon fiber/epoxy prepregs for the stabilizer bars are made in-house, designed and manufactured using a specially formulated epoxy matrix system. Pictured is IFA's small-volume prototype prepregging line, from Santex AG (Tobel, Switzerland). Source | IFA Composite GmbH

3 Prepreg is cut and fed into a mechanized preform assembly station.
Source | IFA Composite GmbH

4 Preforms are placed into a single-cavity tool (shown here), the tool is closed and an inner silicone bladder is inflated. Parts are cured in less than 20 minutes in a 1-MPa press at 130°C, then post-cured for two hours.
Source | IFA Composite GmbH

its tendency to turn more or less than commanded, respectively.

A stabilizer bar is situated between the left and right wheels, connecting them through short lever arms linked by a torsion spring. The bar is attached to the car chassis through rubber bushings. Stabilizer bars can be solid or hollow, and designed as monolithic — a single bar — or as a multi-component assembly, with separate lever arms.

"The discrete loading of a stabilizer bar — torsional load in the middle section and bending load in the lever arm — is an opportunity for composites' tailorable anisotropy to provide a lightweight, efficient design," explains Christian Schulz, head of composite structural parts at IFA Composite. Achieving not only a significant reduction in weight, but also a wider range of stiffness within the same outer shape, composites offered a solution, says Schulz, when requirements in the installation space could no longer be met using standard steel stabilizer bars. "Composite designs allow options which are harder to produce in steel."

Process drives design

"As a high-volume manufacturer, streamlined production is the key for cost-effective parts," says Schulz. R&D will always seek to make the parts lighter, he notes, "but optimal 'rocket science' designs could easily be too expensive for the added weight benefit." The process IFA developed includes a preforming station, a molding press and a CNC machining center (see Fig. 2, p. 33). Once the production process was set, Schulz says the steps were easily separated and simplified, so that parts could be fabricated in a smaller, limited-volume production environment, and then scaled up as necessary. "Currently, the parts are manufactured with limited machinery," Schulz comments, "but the whole

5 CNC machining centers, like these used for IFA's composite leaf springs, will be used to finish demolded stabilizer bars as production volumes increase. Source | IFA Composite GmbH

7 These pre-production CFRP stabilizer bars for the VW *XL1* passed all OEM-mandated tests in IFA Composite's extensive test center.
Source | IFA Composite GmbH

6 Finished prototype and production parts are NDT tested using automated ultrasound scanning.
Source | IFA Composite GmbH

process can be readily scaled to semi-automated and then fully automated production."

Next came refinement of the CFRP structural design, based on each program's specific requirements. For example, the front and rear stabilizer bars for the *XL1* are monolithic and hollow. Schulz explains that they are molded in a steel cavity tool, using a customized blow molding process, inner silicone bladder and air pressure. Because this molding system accommodates a wide range of laminate thicknesses, it enables nearly infinite stiffness variations within the same outer shape by varying the fiber layup. Each bar also varies in cross-sectional shape, having round as well as oval or even nearly square sections. "The path of the composite bar is not limited to bends, as traditionally used in steel production, but allows far more complex, organic freeform spline sections," says Schulz. (*Splines*, in computer design, refers to curves that connect or are defined by two or more specific points.) All of this enables significant design freedom during the CAD and FEA processes, for which IFA Technology and IFA Composite use the composites software suite from ANSYS (Canonsburg, PA, US).

The outcome of these efforts is a part made using carbon fiber prepreg. "This choice allows for superior consolidation in the parts, resulting in consistent stiffness and lifetime expectancy," says Schulz. »

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Read more about this topic in "Composite leaf springs: Saving weight in production suspension systems" online | short.compositesworld.com/leafspring

Read more about IFA in "World's first glass fiber leaf spring for 40-ton trucks" online | short.compositesworld.com/40TonLeaf

Given its long history in producing reliable suspension parts from *glass fiber* prepreg, IFA Composite designed and manufactured this new carbon fiber prepreg in-house, using a specially formulated epoxy matrix system. The company uses a smaller volume prototype line and a full-scale inline impregnation line (See Step 2, p. 34 and Fig. 3, p. 33) supplied by Santex AG (Tobel, Switzerland).

With a final design in hand and materials selection complete, the next step was preform manufacture. "It is critical that all fiber angles are exact, so we designed a special machine to cut and assemble the prepreg layers," Schulz explains. Currently, only the assembly process is machine supported. Preforms are then placed by hand into a single-cavity tool, which has been prepared using mold release from Chem-Trend Germany (Maisach/Gernlinden). The tool is then closed and the inner silicone bladder is inflated with air.

"When we started in 2011, the curing cycle was 40 minutes," says Schulz, "but now it is reduced by half, to less than 20 minutes, using 1 MPa pressure at 130°C."

When the part is cured, the liner is removed and the parts are post-cured for two hours. For the current limited-production quantities, molded parts are trimmed and drilled manually. When production volume increases, this will change to CNC-machining, similar to the company's process for leaf springs (see Step 5, p. 35).

Prototype parts are tested in IFA's extensive test center (which houses burst, crash, noise/vibration/harshness (NVH), acoustics and service-life test systems as well as climate chambers capable of -41°C to 75°C and up to 80% relative humidity) against real road data diagrams defined by the OEM. Automated nondestructive testing equipment is available for both prototype and production parts (Step 6, p. 35). The CFRP stabilizer bars for the Volkswagen *XL1* passed all required performance tests, yet weighed only 786g for the rear axle and 1,159g for the front. Those weights are extremely low, however, because the *XL1* hybrid is designed to travel 100 km on one liter of fuel. Newer stabilizer bars designed for high-performance sports cars weigh closer to 1,250g, but that is still half the mass of their metallic counterparts.

Opportunities for carbon *and* glass

IFA Composite already is using the process developed for its stabilizer bars to broaden its pursuit of production-scale CFRP suspension structures. It has since developed structural CFRP chassis components that include not only leaf springs and anti-roll bars, but torsional springs and other suspension parts — and broadened its production to other high-performance automobiles.

Although the *XL1* stabilizer bar uses a monolithic design, Schulz sees growth in multi-part assemblies, similar to those developed for a new sports car. "It allows even more design freedom with mix-and-match lever arms and also hollow torsional tubes," he explains. "With almost the same weight as the *XL1* parts, these stabilizer bars are six times stiffer!"

The big question is will this technology go into high-volume production? IFA Composite's product group leader Hinrich Hampe sees that future for CFRP *and* GRP chassis components. "The advantages, like good failure modes and lightweight design, are valued, both for today's cars and future models," he says. "We also see options for torsional springs, which can be made more compactly than metallic components, opening up totally new layout options." Hampe adds, "Due to the high cost of carbon fiber raw material, it will be limited to sports cars and electric vehicles, but glass fiber offers an alternative still underestimated today." CW

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Composites Events

Aug. 22-25, 2016 — St. Paul, MN, US
CMH-17 PMC Coordination Meeting
CMH-17.org

Aug. 23-25, 2016 — Detroit, MI, US
5th Annual Global Automotive Lightweight Materials (GALM) Detroit 2016
global-automotive-lightweight-materials-detroit.com

Aug. 28, 2016 — Gramado, Brazil
Brazilian Conference on Composite Materials (BCCM)
bccm.com.br/bccm3

Aug. 31-Sept. 2, 2016 — Shanghai, China
China International Composites Expo
chinacompositesexpo.com/en

Sept. 7-9, 2016 — Novi, MI, US
SPE Automotive Composites Conference and Exhibition (ACCE)
speautomotive.com

Sept. 13-14, 2016 — Chicago, IL, US
Additive Manufacturing Conference 2016
additiveconference.com

Sept. 13-15, 2016 — Liege, Belgium
SAMPE Europe Conference & Exhibition
sampe-europe.org/conferences/liege-2016

Sept. 19-21, 2016 — Toulouse, France
SpeedNews 17th Annual Industry Suppliers Conference
speednews.com/aviation-industry-suppliers-conference-in-toulouse

Sept. 21-23, 2016 — Augsburg, Germany
Experience Composites
experience-composites.com/en

Sept. 26-29, 2016 — Anaheim, CA, US
CAMX – Composites and Advanced Materials Expo 2016
thecamx.org

Sept. 27-30, 2016 — Hamburg, Germany
WindEurope Summit and WindEnergy Expo
windenergyhamburg.com/en

Oct. 4-6, 2016 — Tampa, FL, US
IBEX 2016
ibexshow.com

Oct. 5-7, 2016 — Los Angeles, CA, US
Greenbuild International Conference and Expo
greenbuildexpo.com

Oct. 19-22, 2016 — Goyang, South Korea
SAMPE Korea 2016
nasampe.org/m/event_details.asp?id=797466

Nov. 2-3, 2016 — Birmingham, UK
Advanced Engineering UK
advancedengineeringuk.com

CW Nov. 9-11, 2016 — Scottsdale, AZ, US
Carbon Fiber 2016
carbonfiberevent.com

Jan. 23-24, 2017 — Paris, France
ICCM Paris – 19th International Conference on Composite Materials
waset.org/conference/2017/01/paris/ICCM

March 13-15, 2017 — Beverly Hills, CA, US
SpeedNews 31st Annual Commercial Aviation Industry Suppliers Conference
speednews.com/commercial-aviation-industry-suppliers-conference

March 14-16, 2017 — Paris-Nord Villepinte, France
JEC World 2017
jeccomposites.com

March 26-30, 2017 — New Orleans, LA, US
NACE Corrosion 2017
nacecorrosion.org

April 4-6, 2017 — Hamburg, Germany
Aircraft Interiors Expo 2017
aircraftinteriorsexpo.com

April 4-6, 2017 — Detroit, MI, US
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COMPOSITE TANKS BEST STAINLESS STEEL OVER ROAD, RAIL AND SEA

One-piece, filament wound containers cost less, hold more, last longer.

Den Hartogh Logistics' (Rotterdam, The Netherlands) fleet of more than 19,000 tank containers now includes composite tanks manufactured by Tankwell (Wieringerwerf, Netherlands). Source | Aliancys

Tankwell containers are made in one filament winding operation, instead of the conventional method, which mates separate end-caps with a filament wound cylinder. Source | Aliancys

An external frame is incorporated in the tank's overall design for rigidity and mechanical integrity. Access manholes, valves and auxiliary components, shown here, are standard metallic parts, integrated into the composite structure. Source | Aliancys

› Given increasing competition in the European road and intermodal transport market, transportation carriers across the region are seeking opportunities to increase payload and/or reduce freight cost. In search of a lighter, less maintenance-intensive tank container with a 15- to 20-year service life, Den Hartogh Logistics (Rotterdam, The Netherlands), which fields a chemical transport fleet fitted with more than 19,000 stainless steel tank containers worldwide, managed to connect with a relatively new Dutch company, Tankwell (Wieringerwerf, The Netherlands), a spinoff brand of Wieringerwerf-based Composite Production Technology.

Tankwell introduced, in 2015, a novel technology for manufacturing large composite tanks, explains Casper Willems, managing director: "The entire tank is made in one filament winding operation, instead of the traditional method of mating separate end-caps with a filament wound cylinder. This means the wall thickness of the composite tank is lower than for comparable composite tank structures." Willems adds that an external frame is incorporated in the overall design, resulting in an assembly with excellent rigidity and mechanical integrity. Access manholes, valves and auxiliary components are still standard metallic parts, integrated into the composite structure.

Tankwell manufactures the large bulk tanks, using trademarked Atlac 5200 FC vinyl ester resin from **Aliancys** (formerly DSM Composite Resins, Schaffhausen, Switzerland), delivered by distributor **Euroresins** (Budel, The Netherlands). The high-strength vinyl ester can be tailored to resist a broad range of chemicals. Rob van de Laarschot, head of technical service at Aliancys, says, "In order to fit tanks for specific chemicals, we can build on our chemical resistance information system, based on years of resin chemical resistance testing."

The composite tank container has received all relevant approvals for carrying chemicals, after extensive material and product testing under third-party oversight, including fire-safety and mechanical-impact testing. Den Hartogh Logistics began using the composite tank containers in its fleet in December 2015, and the results reportedly have been impressive: The 31,000L composite "swap body" tank container (transportable either by truck, rail car or ship) weighs 2,200 kg, 40% less than a traditional stainless steel tank. Nevertheless it holds 2 MT more product, says Jacco van Holten, commercial director at Den Hartogh Logistics. The overall result is a 5-10% reduction in freight cost per shipment. Further, the composite tank's inner surface is smoother and resists chemical corrosion and pitting, and therefore requires less scrubbing and rinsing during product changeover. CW

Carbon fiber lightens medical laser chassis

Reduced weight shortens surgical and diagnostic procedures.


Source | Dexcraft

Lasers have been used in industry since the 1960s. They are now commonly employed in many surgical procedures, such as cataract, tumor and lesion removal, vision correction, and cosmetic surgery, and they also play a role, today, in a wide range of medical diagnostic procedures. Dexcraft (Wołomin, Poland) manufactures medical laser chasses, using carbon fiber-reinforced epoxy composites. "It lightens the chassis by roughly 40%, resulting in a 4-kg weight vs. aluminum at 6.5 kg," says owner Artur Kiliański. "The lower weight makes the laser move faster, which reduces the time required for medical procedures and makes the laser easier to control." The much lower starting cost offered by manufacturing with carbon fiber composites also is a key benefit. "The molds only require a 3D drawing," notes Kiliański, and he says the cost of mold build is about €3,000-€4,000 (US$3,410-US$4,550).

"Starting manufacture of this element from aluminum or steel is much more expensive," he contends, pointing out that this is especially true for manufacturers who produce specialty items at low volumes, for example, 50-100 units per year. Carbon fiber also helped Dexcraft's customer to differentiate its products. "The client wanted to offer a lightweight, premium-quality product, and the easily recognized look of aesthetic carbon fiber connotes both immediately."

Dexcraft provides custom carbon composite manufacturing. The company also supplies pre-cured sheet laminates and other standard products for the automotive aftermarket, sporting goods and consumer goods markets. CW

New Products

» VACUUM SYSTEM EQUIPMENT & ACCESSORIES

Lab-scale vacuum system

Oerlikon Leybold (Cologne, Germany) has introduced TURBOLAB "plug-and-play" high-vacuum pump systems for lab-scale and research-and-development (R&D) applications. The compact systems reportedly are available in different configurations to cover individual vacuum demands in a range of R&D and analytical scenarios. In addition, hydro-carbon-free pump system operation is said to be guaranteed, due to the oil-free, hybrid bearing design of the systems' new TURBOVAC i/iX turbo pumps and the use of different dry compressing backing-pump combinations. The TURBOLAB systems come fully assembled and ready to operate, with a turbo-molecular pump, a dry-compressing or oil-sealed backing pump and a TPU display power unit. Compact tabletop and mobile cart versions are available, and both offer flexibility and ease of operation. Each can be customized to accommodate a range of accessories, including purge gas and/or venting valves, a foreline safety valve, cooling units and a heater band. The system also can accommodate THERMOVAC TTR vacuum pressure gauges and PENNINGVAC PTR high-vacuum sensors. Connected sensors are detected and pressure readings are automatically shown on the display. TURBOLAB Data Viewer, a PC-based software tool, analyzes the data log and event log files and monitors the status and key parameters in real time. A built-in Webserver enables remote control, monitoring and configuration of TURBOLAB from a mobile device or computer, using a browser. **www.oerlikon.com**

» NOISE, VIBRATION & HARSHNESS DAMPING MATERIALS

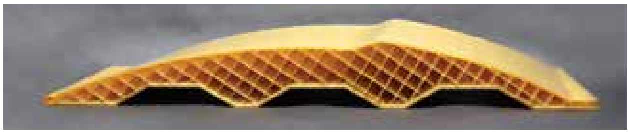
Aircraft interior skin-damping materials

SMAC (Toulon, France) has introduced SMACSONIC, a new range of skin-damping materials, designed to replicate the efficiency of current SMACSONIC products, but at a lower weight. Developed to reduce vibration and induced noise created by a structure, the range includes SMACSONICST2, which complements existing SMACSONICST, for ambient temperature applications, and SMACSONICEX2, which complements existing SMACSONICEX, for low-temperature applications. SMACSONIC damping products are used on lightweight structures, including fuselages, fairings, cabinets, crew rest compartments and monuments. For composites fabricators, the company also offers the SMACWRAP range, which includes SMACWRAP VEIL, a very thin damping material that can be embedded in a layup to save weight, space and energy while ensuring high performance.
www.smac-sas.com

» ADDITIVE MANUFACTURING EQUIPMENT & MATERIALS

Fused deposition modeling design guide and more

Stratasys (Eden Prairie, MN, US) has launched a comprehensive design guide for users of its Fortus-brand fused deposition modeling (FDM) systems, titled *Design Guide for FDM Composite Tooling*, that lays out



the best practices for design, fabrication and preparation of 3D printed composite tools that can be used to cure composites at temperatures exceeding 177°C under pressures as high as 100 psig. Tim Schniepp, composites tooling director at Stratasys, points out that the *Guide* demonstrates how a combination of ULTEM 1010 PEI resin material (supplied by **SABIC**, Pittsfield, MA, US) and the FDM process enables manufacturers to produce tooling for autoclave-curable composite structures in a fraction of the time that traditional metal molds require, and does so at significant cost savings. In a recent SAMPE technical paper, Schniepp noted that Dassault Falcon Jet (Little Ferry, NJ, US) has employed this tooling solution for parts on its *Falcon* aircraft: "We developed the *Design Guide* to provide our customers with the ability to immediately realize the immense time and cost-saving benefits of FDM composite tooling without the effort and expense required to develop the knowledge independently."

Stratasys also offers a 3D printed sacrificial (trapped) tooling solution. Using a new "washout" material called ST-130 together with a patent-pending "alternative fill" printing pattern, the tooling is designed for rapid build speed, fast dissolution, yet yields a high-quality tool that can be autoclaved.

Stratasys also offers an Acceleration Kit for its Fortus 900 printing machines, intended for ULTEM 1010 and ASA polymer materials and aimed at producing large tools. A larger extrusion tip and upgraded software package allows faster material laydown rate for faster builds.
www.startysys.com

» PUBLICATIONS, VIDEOS & RESOURCE MATERIALS

Thermoplastics handbook updated

CRC Press LLC (Boca Raton, LA, US) has published the *Handbook of Thermoplastics, Second Edition* (ISBN 9781466577220) by Olagoke Olabisi (Corrpro Cos. Inc., Houston, TX, US) and Kolapo Adewale (Hanwha L&C Alabama LLC, Opelika, AL, US). This new edition of a bestseller incorporates recent developments and advances in thermoplastics with regard to materials development, processing, properties and applications. With contributions from 65 internationally recognized authorities in the field, it offers up-to-date coverage of commodity, transitional, engineering, high-temperature and high-performance thermoplastics (including thermoplastic composites).
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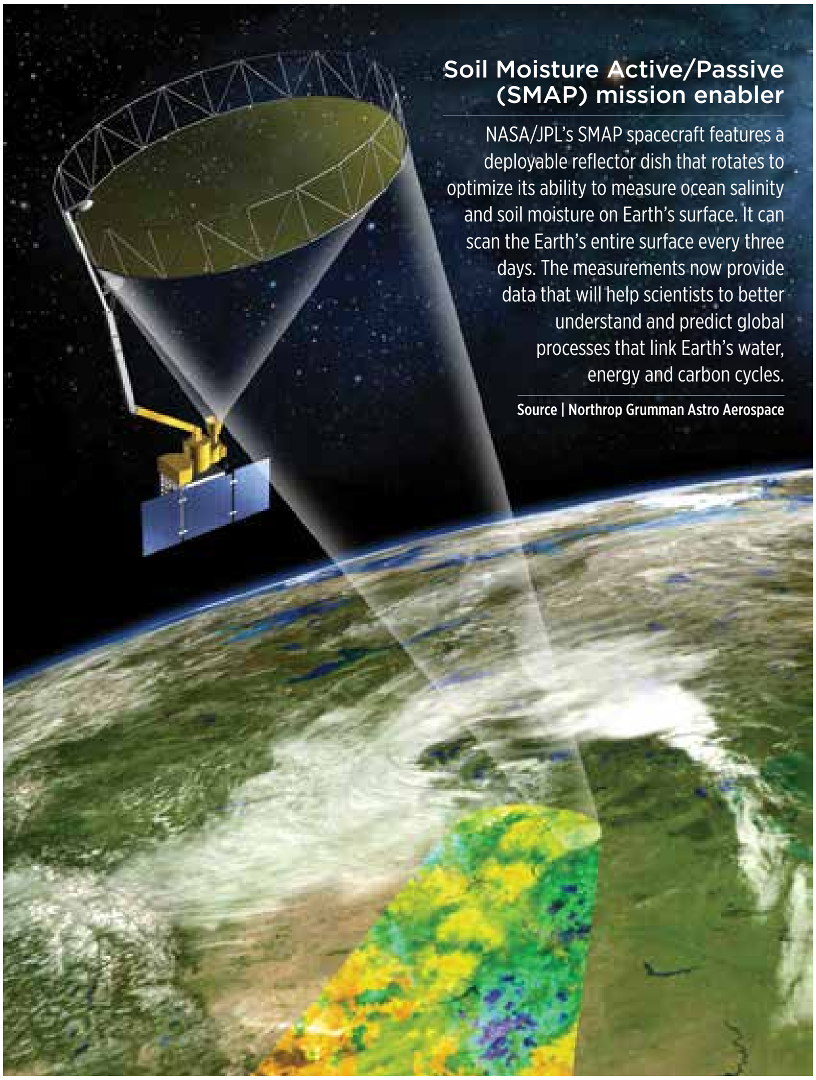
Enabling SMAP mission success, unprecedented design requirements were deftly managed using composites in the largest unfurling and rotating reflector to date.

By Ginger Gardiner / Senior Editor

» In 2015, NASA's Jet Propulsion Laboratory (JPL, Pasadena, CA, US) launched the Soil Moisture Active/Passive (SMAP) mission to measure ocean salinity and soil moisture from low-Earth orbit (LEO). SMAP's single spacecraft used new instrumentation, comprising an L-band radar and an L-band radiometer with a shared feedhorn and a 6m mesh reflector dish.



Soil Moisture Active/Passive (SMAP) mission enabler

NASA/JPL's SMAP spacecraft features a deployable reflector dish that rotates to optimize its ability to measure ocean salinity and soil moisture on Earth's surface. It can scan the Earth's entire surface every three days. The measurements now provide data that will help scientists to better understand and predict global processes that link Earth's water, energy and carbon cycles.

Source | Northrop Grumman Astro Aerospace

The reflector is cantilevered out from the spacecraft by a 3.35m long articulated boom. The feedhorn, reflector and boom assembly (RBA) rotate at 14.6 rpm, so that a 1,000-km-wide swath on Earth's surface can be measured continuously, enabling complete scanning of the planet's surface every three days.

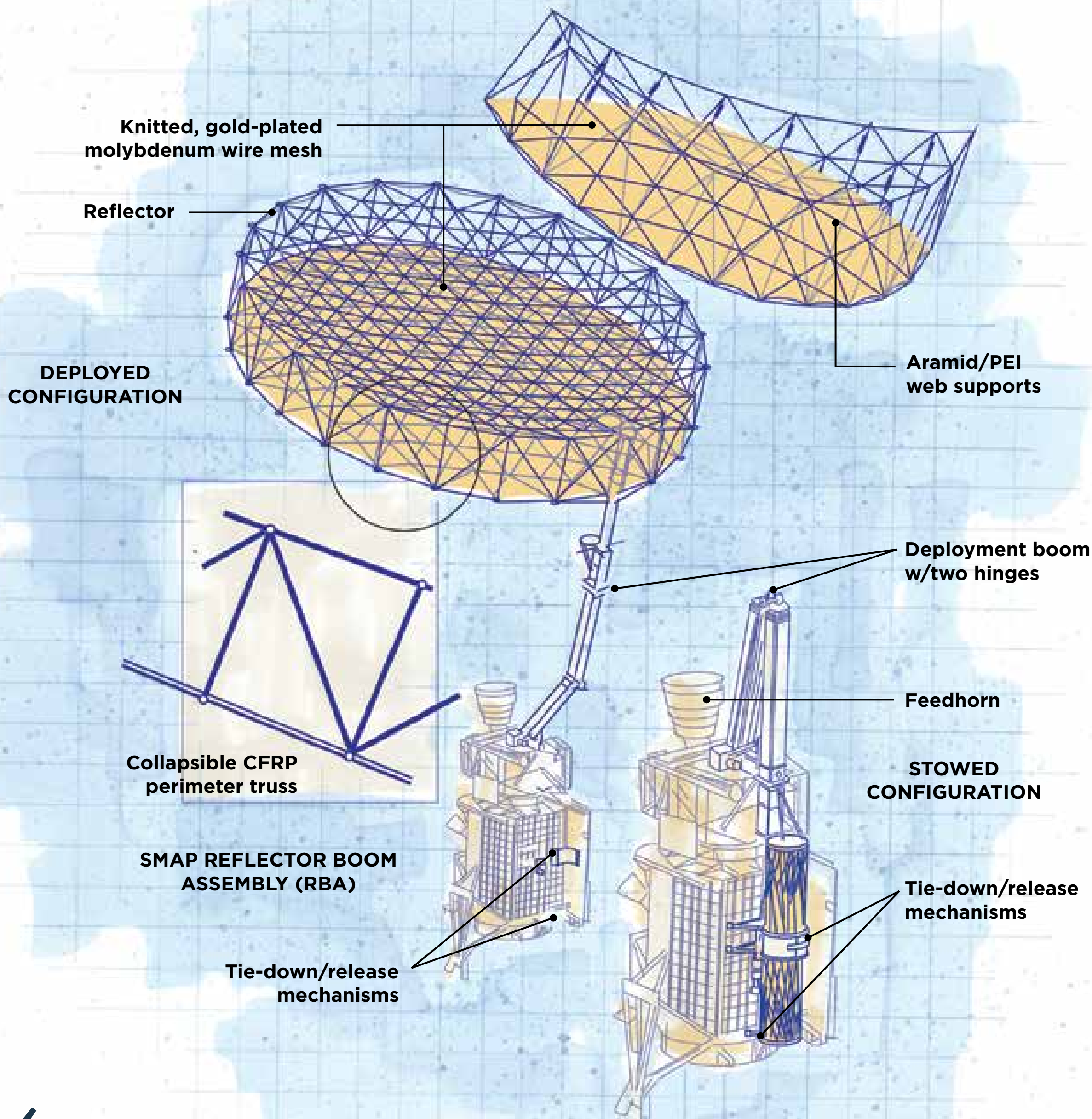
"The requirements for the rotating RBA on SMAP were unprecedented in scope," says Daniel Ochoa, the product development manager at Northrop Grumman Astro Aerospace (Carpinteria, CA, US) and part of the engineering team responsible for the final design. "Not only did the deployable RBA have to be exceptionally light and stable to minimize deflection during high-speed rotation, it also had to have extremely accurate and predictable mass properties when spinning."

Established in 1958 as Astro Aerospace, Ochoa's group is now a business unit of Northrop Grumman Aerospace Systems (Redondo Beach, CA, US). "Our deployable antennas and structures are orbiting the Earth, the Moon and Mars, and traveling beyond our Solar System on the *Voyager* spacecraft, still measuring the effects of solar winds and magnetic fields 35 years after launch," he says. With a 100% success rate in mission deployments, the group understood the design challenge SMAP presented. "SMAP is the largest rotating reflector, as well as the largest mass-balanced reflector, ever built. We've built reflectors 12m in diameter, but *they* don't spin."

The dish was designed to be deployable, furled into a small space — 1.83m by 0.36m — for launch, and then, after entry into orbit, *un*furled to form a precise reflective surface.

Precise, accurate focus in motion

To the SMAP's L-band radiometer, very dry soil on Earth appears to be about 300°K. Very moist soil shows as roughly 100°K. These are not physical temperatures, but the temperature of naturally occurring L-band emissions from Earth's surface. "By measuring the brightness



DESIGN RESULTS | **Northrop Grumman SMAP Deployable Reflector Dish**

- A 6m-diameter composite reflector frame that could be collapsed into a 1.83m by 0.36m envelope for launch, weigh less than 13 kg and then deploy as expected in the zero-gravity LEO environment.
- A composite boom stiff enough to extend the reflector 3.35m off the spacecraft's spin deck at a 40° angle and to hold the antenna in expected alignment without distortion at 14.6-rpm rotation speeds.
- The reflector boom assembly (RBA) corrects the spin-induced constant pointing error (caused by centripetal forces) by 350 millidegrees, and accounts for a 2-cm deflection in the reflector tip furthest from the boom.

Illustration / **Karl Reque**

temperature of a plot of soil, you can quickly estimate what the water content is down to about 4% accuracy, which is pretty incredible," explains Kent Kellogg, JPL's SMAP project manager. He notes that the L-band radar is much less accurate but contributes high resolution. "The real aperture resolution of the radiometer, which is basically the spot size it reads on Earth, is 40 km," says Kellogg. "But with the radar, we can generate what's called a *synthetic aperture* by making a series of measurements as the satellite is orbiting overhead." Kellogg says this creates a virtual antenna that's much larger than the 6m reflector, improving the radar's resolution to as fine as 1 km.

Thus, the accuracy of dish size *and* shape are key. Kellogg likens it to a parabolic mirror with a flashlight out in front at the focal point. All the light rays are collected by the mirror into a focused beam, »

Fig. 1 Collapsible, but supportive and precision-shaped

The AstroMesh Lite reflector for SMAP uses aramid fiber/PEI composite webs to support and shape its radar-signal-reflective, gold-plated molybdenum mesh surface, attached to a CFRP circular perimeter truss.

Source | Northrop Grumman Astro Aerospace

instead of scattering if the light were pointing into open space. For the SMAP reflector antenna, the radar feed is similarly placed at the focal point of the parabola. The boom holds the reflector out in front of the light bulb, which, in this case, is the radar and radiometer feed, so that all of the radio frequency (RF) energy leaves collimated (in parallel), focused into a fairly tight beam.

Lightweight composite solution

For the SMAP reflector, Astro Aerospace chose its latest and lightest AstroMesh Lite product line. Optimized for 3-8m aperture reflectors, its surface is a knitted, gold-plated molybdenum wire mesh supported by hundreds of aramid-reinforced polyetherimide (PEI) tapes. "We approximate a perfect parabolic surface via a supporting lattice of triangular facets made from these composite webs," Ochoa explains. The tapes use Twaron T2200 fiber (2420 dtex), supplied by Teijin Aramid (Arnhem, The Netherlands), and Ultem 1010 PEI from SABIC (Pittsfield, MA, US).

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In a proprietary process, the tape is pultruded by TenCate Advanced Composites (Morgan Hill, CA, US). The composite webs — some as long as 6m — were welded together to form the support lattice, which was then attached to a collapsible circular perimeter truss structure made from carbon fiber-reinforced epoxy tubes and bonded joints (see Fig. 1 and Learn More, above).

"When the truss structure is fully deployed," says Ochoa, "it pulls the mesh and composite webs into tension, like a drum or high-performance tennis racket." Astro Aerospace structural engineering manager Michael Beers says the thermoplastic composite offers "a good balance between flexibility — allowing us to compact the whole structure, yet deliver the required stability — and stiffness, once deployed." The composite construction was a key to meeting mass requirements: The reflector weighs in at 25 kg, and the system, with boom, totals a mere 58 kg.

Modeling to meet mass balance requirements

"We provided very accurate mass data, moments-of-inertia and center-of-gravity specifications to JPL so they'd know the precise characteristics of this reflector," Ochoa recalls. "We modeled and weighed each one of our 15,000 individual parts as we were building them, then again in different phases of construction, through to final assembly." He notes that the mass measurements they needed were so unprecedented, "we had to invent new methods to acquire them." For example, machines used to balance aeroengine blades were brought in for some tests. "They were so sensitive that breathing near them skewed the results," Ochoa quips. He explains this level of accuracy was imperative, "because the large reflector, designed to function in the microgravity of space, could not be cost-effectively spun-up in the 1G of Earth, so we had to be absolutely certain before launch."

The RBA mass had to be kept within a 99g window, and the center of mass within 12.7 mm. The boom had to extend the reflector 3.35m off the deck of the spacecraft at a 40° angle and be stiff enough to maintain expected alignment without distorting the reflector surface when spun up to 14.6 rpm. "The shape of the reflective surface defined by the composite webs must be exact to provide the required radar performance," explains Ochoa. "The CFRP boom also would deflect with the load of the dish, so then the reflector moves as a result," he adds.

To compensate for the deflection, says Beers, "we had to predict deflections for spinning, using computer modeling, and also

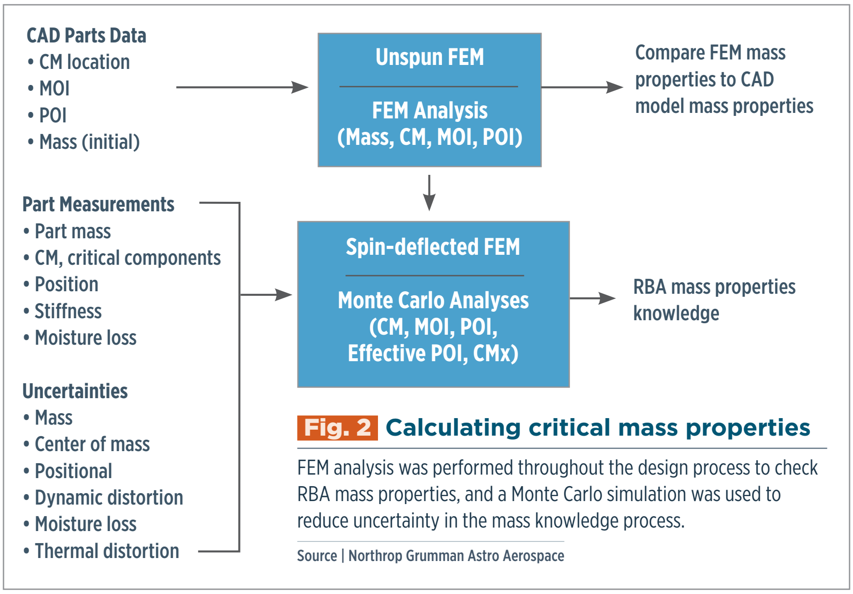


Fig. 2 Calculating critical mass properties

FEM analysis was performed throughout the design process to check RBA mass properties, and a Monte Carlo simulation was used to reduce uncertainty in the mass knowledge process.

Source | Northrop Grumman Astro Aerospace

Fig. 3 Furled and ready for launch

The RBA, with reflector and hinged boom collapsed and secured for launch, is shown ready for transport to rendezvous with its launch vehicle before it went into space and successfully unfurled in 2015.

Source | Northrop Grumman Astro Aerospace

account for the deformations in the structure and mesh due to spinning."

"We built the reflector and boom knowing exactly how the spinning shape would differ from the original shape," Ochoa explains. "We had to make sure that the reflector shape changed in a controlled manner, so we attached specific masses, or counter-balances, on the reflector where necessary."

There also was a strict tolerance — 350 millidegrees — on where the RBA would point, i.e., where it would reflect the RF beam. Ochoa translates, "One millidegree rotation of our assembly translates to an offset of about the thickness of a hair at the reflector tip."

Details of deployable structure design

The minimum resonant frequency for the stowed RBA was 50 Hz in the axial direction and 35 Hz in the lateral. It also had to resist random vibration during launch. Femap with NX Nastran by Siemens PLM Software (Plano, TX, US) was used to develop multiple finite element models (FEMs) and perform various stowed RBA vibrational analyses.

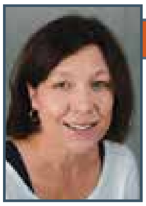
Femap also was used to calculate the RBA's mass properties and then re-run the mass properties model throughout the design process to ensure that the effective product of inertia (POI) and center of mass (CM) remained within required limits.

Large uncertainties at the beginning of the RBA design process prompted a sensitivity study. A Monte Carlo simulation based on a Femap-created FEM was used to examine the effects of seven sources of uncertainty (see Fig. 2, above) on the RBA mass properties. The simulation ran 10,000 mass cases, using a uniform distribution of random inputs for each uncertainty. Results showed the required accuracy for part size, CM and positional measurements, and identified parts critical for overall system POI and CM properties. For these, the center of mass was verified with a measurement. The mass from the CAD model was used for all others.

Success in space

When the satellite was finally launched, positioned in LEO and spun up to operational speed, SMAP's RBA deployed as planned. JPL mission control reported that system alignment was and still is about as close to perfect as it could get. Northrop Grumman Astro Aerospace's lengthy design process and hard work clearly paid off. In late 2016, the company also was awarded the contract to supply the 12m diameter AstroMesh reflector for JPL's NISAR (NASA Isro Synthetic Aperature Radar) mission.

What's next? "The market for large mesh deployable reflectors is very strong," says Ochoa. "There are requests for products from all across the space spectrum, such as *Starshade*, a NASA/JPL mission to identify Earth-like planets in other star systems. "Composites already feature heavily in our preliminary designs for *Starshade*," says Ochoa, "as well as for the large aperture deployable antenna for the NISAR spacecraft, which is designed to observe and measure some of the planet's most complex processes." He is confident that composites and Astro Aerospace are up to the challenge. CW



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