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July/August 2019
Volume 63 Number 4
pp. 163–220

Image: Victrex and Coriolis Composites have formed a partnership to improve thermoplastic unidirectional tape (TP UDT) prepreg lay-up and consolidation and improve the manufacturing efficiency of composite parts. The companies have tested using automated fiber placement (AFP) process with Victrex' AE 250 UDT for aerospace applications.

REGULAR SECTIONS

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RP Rewind

Liz Nickels leafs through past issues of Reinforced Plastics to find out what was happening in the PM industry of the past.

Five years ago...

Reinforced Plastics featured a novel use for composite resins as Huntsman Advanced Materials' Araldite material was used by Nägeli Swiss AG, a manufacturer of composite parts and prototypes, to develop a trumpet bell made from carbon fiber reinforced plastic (CFRP) (Fig. 1).

According to the manufacturers, making wind instruments from carbon fiber compounds means that vibrations in the tube can be suppressed – thus saving energy. The trumpet bell was made using resin transfer molding (RTM) technology. Dry fibers in the form of braided tapes were preformed and placed in a mold and resin was injected into the closed and heated mold. A vacuum was applied, resin injected at high pressure and after the curing cycle, the finished part was demolded.

Blind tests at the time showed that the daCarbo traumpet corresponded to the tone characteristic of the typical conventional trumpet sound and could be readily accepted in professional orchestras. The specific geometry of the bell also gives it an exceptionally clear tone, the companies said. Famous musicians such as Arturo Sandoval, Jon Barnes and Roy Hargrove tested the daCarbo trumpet.

10 years ago...

Alternative fuel was the focus of this issue. 'Fossil fuels still account for the vast majority of the world's energy consumption, but the search for pollution-free, sustainable alternatives is stepping up considerably,' explained editor Amanda Jacob. 'In the transport sector, where environmental pressures are high, a number of alternatives to petrol and diesel are in development and testing. One of these is solar power, and numerous projects demonstrating the potential of solar powered vehicles are underway.' This July, the Solar Impulse aircraft completed its first night flight, powered only by solar energy stored during the day. As the first solar aircraft able to fly day and night, the next challenge for Solar Impulse was to fly around the world without using any fuel or producing any pollution – a task it finally succeeded in accomplishing in 2016, piloted by company founders Bertrand Piccard and André Borschberg.

20 years ago...

'The composites industry likes to think of itself as one of the critical technologies for the future – after all composites offer design freedom and parts consolidation, lightweight, and excellent lifetime costs,' said managing editor Amanda Jacob. 'But where do composites sit in the bigger picture of technological development at the beginning of the 21st century?

FIGURE 1

Nägeli Swiss AG, a manufacturer of composite parts and prototypes, worked with Huntsman Advanced Materials to develop a trumpet bell made from carbon fiber reinforced plastic (CFRP).

'The composites opportunities in the wind energy sector alone are significant – tens of thousands of tonnes of composites are already used in blade manufacture,' she noted. 'But it's not only power generation that's changing – energy used in vehicles will also become increasingly non-fossil fuel. The first commercial fuel-cell powered cars will be on our roads in a few years' time and they may well have lightweight composites bodies. And even if the fuel cell does not kill the petrol engine, conventional cars will need to be lighter to improve their power to weight ratios – it could be a win–win situation for composites.'

1369-7021/https://doi.org/10.1016/j.repl.2019.05.007

ELSEVIER

Applications

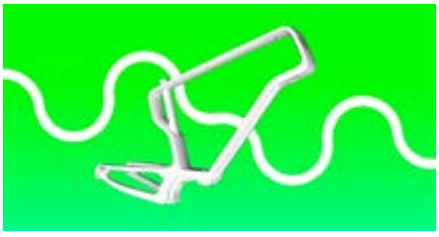
Continuous CF bike frame

Arevo, which makes composite manufacturing software, has formed a partnership with bike manufacturer Franco Bicycles to make a 3D printed, continuous carbon fiber single-piece unibody frame.

The frame will form part of a new line of eBikes Franco will sell under its Emery brand.

The Arevo frame is made as a single part, in contrast to current composite frames, which are made of many parts glued together, the company says. It features continuous carbon fiber placement and improved structural integrity and stability.

Arevo adds that this technology could lead to volume production of AM-made composite parts made with thermoplastic materials, which are tougher, durable and recyclable, as compared to brittle and non-recyclable thermoset materials, a replacement of a laborious manual process with a fully-automated, production model, and much greater freedom of design.



The frame features continuous carbon fiber placement and improved structural integrity and stability.

'This is the first composite additive-manufactured bike frame and it represents an important milestone for the AM industry as Arevo is delivering on the promise of on-demand manufacturing of composite parts in volume now,' said Hemant Bheda, Arevo co-founder and chairman. 'With the introduction of the Emery One, the transformation of the global composite bike industry has begun.'

Arevo; www.arevo.com

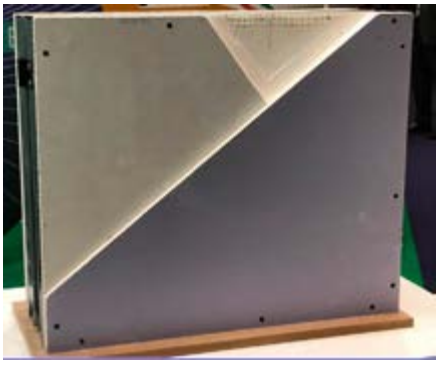
0034-3617/https://doi.org/10.1016/j.repl.2019.06.043

Glass scrim helps secure construction

Chomarat, which makes a range of textiles, says that its laid glass scrim has been used to reinforce attack-resistant gypsum plasterboard made by UK construction specialist Siniat Securtex.

According to Siniat Securtex, it is the first plasterboard-only system certified to Loss Prevention Standard (LPS) 1175 and accredited by the UK's Secured by Design Police Initiative.

The high-tensile glass scrim is combined with a dense gypsum core to help protect the building construction, because it can help dissipate the force across the whole area of the board, providing impact resistance.



The high-tensile glass scrim is combined with a dense gypsum core to help protect the building construction. (Photo courtesy Siniat Securtex.)

'Chomarat laid glass scrim brings extra mechanical strength and impact resistance to party walls and doorsets,' said Pierre Peyron, industrialisation engineer for Securtex. 'Combined with a dense gypsum core, it prevents damage from tools typically used by opportunistic burglars, such as screwdrivers or from physical attack, eliminating the need for additional materials such as metal lath or ply in the partition.'

Chomarat; www.chomarat.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.044

Composites for aircraft seating

Rockwood Composites and Haeco Cabin Solutions have formed a partnership focusing on aircraft seating. Haeco has commissioned Rockwood to tool its new cabin platform for seat shells and console work. This bespoke seat will feature compound, molded surfaces and respective tooling design.

Rockwood says that it aimed to design a lightweight structure with enough modularity to allow Haeco to contend with future permutations of the product. While the shapes used in this class are not new, the scale and industrial design are reportedly a first of a kind for this kind of cabin.

'We were looking for a way to optimize these structures for weight, strength, and manufacturability,' said Jose Pevida, HAECO senior vice president.

Rockwood; www.rockwoodcomposites.com

Rockwood Composites and Haeco Cabin Solutions have formed a partnership focusing on aircraft seating.

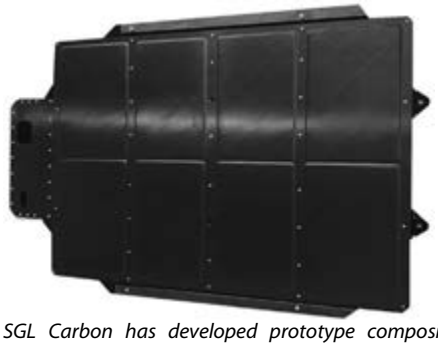
0034-3617/https://doi.org/10.1016/j.repl.2019.06.045

Lightweight composite battery enclosures

SGL Carbon has developed prototype composite battery enclosures that are reportedly 40% lighter than aluminum.

The company worked with Chinese automotive manufacturer NIO to develop the prototypes, which are made of carbon-fiber reinforced plastic (CFRP) for its electric vehicles. The bottom and cover plate design combine a sandwich core with multiple layers of carbon fiber non-crimped fabrics. According to the companies, the battery enclosure is lightweight, stable and safe and it can be changed at swapping stations of NIO within just three minutes.

'Commercial battery enclosures for electric vehicles are mainly made of aluminum and steel,' said Sebastian Grasser, head of automotive at SGL Carbon. 'In comparison, the CFRP battery enclosure is around 40% lighter. Other benefits include the enclosures' stiffness and the approximately 200 times lower thermal conductivity of CFRP compared to aluminum, which better shields the battery from heat and cold. Plus, the composite also offers excellent values in terms of water and gas leakage tightness and corrosion resistance.'



SGL Carbon has developed prototype composite battery enclosures that are reportedly 40% lighter than aluminum.

'Using composite material, especially high-performance carbon fiber in the battery enclosure system, our vehicle can achieve a better dynamic performance, increased range, and obtain remarkably high energy density of the battery pack (over 180 Wh/kg),' said Bin Wei, senior manager at NIO.

SGL Carbon; www.sglcarbon.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.046

Epoxy resins for flying car

Students at the Royal College of Art in the UK have designed a one-seat, carbon fiber, multi-rotor flying vehicle featuring Sicomin's epoxy resin materials.

ENATA Aerospace, based in the UAE, made the vehicle using PEI foam and ultra-thin biaxial carbon fiber non-crimp fabric in a set of 32 molds used to manufacture the car body. The carbon fabric is built up from uni directional layers at different orientations. The completed vehicle is 2.5 m long, 1.5 m wide and has a full carbon fiber frame with a body weight of only 9 kgs.

The internal structure is made up of sandwich panels using carbon fiber fabrics and a nomex honeycomb core material. All body panels were wet laminated, and vacuum consolidated using female molds to provide an improved surface finish, according to the company.

All body panels were wet laminated, and vacuum consolidated using female molds to provide an improved surface finish, according to the company.

ENATA chose Sicomin's SR1700 epoxy system for the structure of the Antelope. According to the company, epoxy resin is stronger than alternative resin types, has good fatigue performance and durability, and is proven to work well when combined with carbon fiber. SR1700 has been formulated to make composites such as aerospace applications. The system has a low viscosity at ambient temperature and can be used with various hardeners for the vacuum moulding of small or large parts. It offers an improved adhesion to a variety of reinforcements such as glass, aramid and carbon, Sicomin says.

Sicomin; www.sicomin.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.047

Fiber-reinforced blades

Tool maker Performance Plastics Ltd has reportedly chosen Solvay's Torlon polyamide-imide (PAI) material to make its line of EnduroSharp scraper blades. The blades are designed to remove tough materials from delicate fiber-reinforced composite surfaces, and are molded from Torlon 5030, a 30% glass fiber reinforced resin.

'The task of removing gap materials, sealants and adhesives from aircraft surfaces once forced maintenance technicians to choose between potentially harmful metal blades and polymer tools that could not hold their edge for long,' said Rich Reed, vice president at Performance Plastics. 'The unique properties of Solvay's Torlon PAI balances the best of both materials. It can be sharpened and hold an edge like metal, but it will not damage delicate composite surfaces.'

Solvay's Torlon polyamide-imide (PAI) material has been used to make a line of EnduroSharp scraper blades.

The blades can also withstand the high heat and friction of resharpening, which can produce burrs on blades machined from PEEK and PEI, Solvay says. Torlon PAI is also resistant to aerospace fluids and solvents.

Solvay; www.solvay.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.048

Epoxy prepreg solution for aero interiors

Total Composite Solutions (TCS) has introduced an epoxy prepreg for the aerospace interiors sector. The material range, developed and manufactured by Microtex Composites Srl, TCS's prepreg partner, can reportedly be used in place of traditional phenolic systems whilst exceeding the requirements of industry standard FAR 25.853.

Total Composite Solutions (TCS) has introduced an epoxy prepreg for the aerospace interiors sector.

'The prepreg solution we are delivering to the market will enable the removal of phenolic chemistry from the sector, a strategy clearly defined by the major market OEM,' said Andy Pointon, MD of TCS. Additional benefits include improved finished part quality and reductions in potential rework, the company said. The material can be oven cured making it possible to manufacture large structures without autoclave curing. All test properties achieved to date have been produced from oven cured laminates.

Total Composite Solutions; www.totalcompositesolutions.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.049

Composite facility receives aerospace certification

TxV Aero Composites, a joint venture between Victrex plc and Tri-Mack Plastics Manufacturing Corporation, has received AS9100 and ISO 9001:2015 certification for a thermoplastic composite part manufacturing facility.

TxV's manufacturing facility was designed and built to form polyketone composite parts for commercial aerospace.

To achieve AS9100 certification, the standardized quality management system for aerospace, TxV defined all process interactions and developed QMS documentation including a quality manual, work instructions and process for maintaining records to achieve compliance with the standard.

'Achieving operational readiness and compliance with AS9100 and ISO standards are key milestones for our growing business,' said Jonathan Sourkes, senior account manager at TxV.

TxV's manufacturing processes are based on Victrex thermoplastic composites and its manufacturing facility was designed and built to form polyketone composite parts for commercial aerospace. The site features automated tape laying, consolidation, forming, and injection molding as well as a quality lab on site to ensure compliance to the quality requirements of the aerospace industry.

TxV Aero Composites; www.txvaero.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.050

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Business

Airbond wins Queen's Award

Airbond, a UK-based fiber splicing company, has reportedly won the Queen's Award for Innovation for its new splicing technology. This is the second Queen's Award the company has achieved, having won another for innovation in 2013.

Splicing carbon or glass fibers with compressed air can turn them to dust as they are brittle, albeit strong longitudinally.

Airbond says that its machines can, for the first time, spliced modern composite materials due to a control of the air with new accessories. The technology involves keeping the splicing units hidden and protected inside a sturdy molded shell, making them much more durable. The outer shells are inexpensive, so that they can be viewed as consumables if covered with resin while the splicers themselves remain pristine.

'Splicing is a mature technology which had stagnated for decades,' said Graham Waters, MD of Airbond. 'We have catapulted it into the 21st century. Get it wrong and you will waste a lot of product, transforming fibers into dust. However, we have invested heavily in R& D to get it right, and we are really pleased at the recognition of this second Queen's Award for Innovation'.

The Queen's Award is a program for British businesses and other organizations who excel at international trade, innovation or sustainable development.

Airbond; www.airbondsplicer.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.002

Industrialization partnership

Solvay and aerospace company Airborne have signed a memorandum of understanding to jointly develop automated processing solutions for the industrialization and high-volume use of composite materials.

According to the companies, industrializing tailored prepreg layups and forming technologies for high volume applications is a significant challenge for the composites industry.

'To truly drive innovation in composites, we firmly believe it is vital to collaborate throughout the value chain, enabling the development of materials, processes and automation to go hand in hand. If we follow such a holistic approach, great breakthroughs are possible,' said Marcus Kremers, CTO at Airborne.

Solvay; www.solvay.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.003

From left to right: Fabrizio Ponte, executive vice-president, Solvay, Arno Van Mourik, CEO, Airborne, Marcus Kremers, CTO, Airborne, Mike Blair, executive vice-president research at Solvay, and Gerald Perrin, global growth sales director, Solvay.

Composites UK appoints new president

Trade organization Composites UK has appointed Ben Wilson as chair for 2019–2021.

Wilson is a business leader at MPM Ltd, a family business established by his father in 1978. Under his direction since 2010, the business has more than trebled turnover with 20% year on year growth with record sales and beating targets every month, Composites UK said.

'I am delighted to have been voted in as chair at Composites UK, they are a fantastic supporter of our industry,' said Wilson. 'With my two years as chair I am dedicated to ensuring members from across all sectors get value from their membership, whilst supporting growth in the UK composites market. I am particularly passionate about apprenticeships and will be looking to get a level 2 aligned with the level 3 that we already have in place.'

Dr Faye Smith, Avalon Consultancy will continue the role of vice chair for the next year, while Chris Taylor, Axon Automotive will step down from his two-year role as chair.

Composites UK also reports that four places on the board are up for election.

Composites UK; www.compositesuk.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.004

3D printing composites sales

CRP Technology, which makes Windform composites for 3D printing, says that the materials will no longer be sold to service bureaus for the toll-manufacture of 3D printing components.

The company says that the composite materials will continue to be available and on sale for companies that directly produce their own components (OEMs).

CRP Technology and CRP USA will also continue to offer 3D printing service producing parts and components in Windform.

The company also recently achieved the ISO 9001: 2015 standard regarding the manufacture of 3D printed parts and the production of Windform composite materials for selective laser sintering (SLS) technology.

CRP Technology; www.crptechnology.com

The company also recently achieved the ISO 9001: 2015 standard regarding the manufacture of 3D printed parts.

0034-3617/https://doi.org/10.1016/j.repl.2019.06.005

DSM sets reduction targets for emissions

International science company Royal DSM says that it has set reduction targets for its greenhouse gas emissions.

The company reports that it has committed to reducing 30% of its greenhouse gas emissions from direct production and purchased energy in absolute terms by 2030 compared to 2016. It also plans to decouple emissions from its growth through energy efficiency measures and sourcing more renewable electricity. DSM will also purchase 75% of electricity from renewable sources by 2030, with 41% already being renewable in 2018, the company says.

The new targets have been reviewed and approved by the Science Based Targets initiative (SBTi) and aligned with the Paris climate agreement. The SBTi is a collaboration between CDP, the United Nations Global Compact, World Resources Institute (WRI) and the World Wide Fund for Nature (WWF), and DSM is reportedly the first European company in its sector to join the group of almost 180 companies with science-based targets.

'We congratulate Royal DSM on setting emissions reduction targets in line with climate science,' said Alexander Farsan, global lead for science-based targets at WWF. 'By taking this ambitious step, they are real leaders in their sector and are doing their part to align with global efforts to prevent the most dangerous effects of global warming.'

DSM; www.dsm.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.006

DuPont wins green chemistry award

DuPont has received Taiwan's inaugural National Green Chemistry Award for its development of a polymer which includes 37% renewable plant-based ingredients, is produced using 30% less energy and releases 63% fewer greenhouse gas emissions as compared to nylon 6.

DuPont says that its Sorona polymer also has improved softness, stain resistance and durability.

The company also won the award for its product life cycle management and efforts to promote green chemistry.

'We are deeply proud to receive the inaugural National Green Chemistry Award,' said Larry Chen, president of DuPont Taiwan. 'DuPont has a long-standing commitment to sustainability in Taiwan, and we are thrilled by the recognition of green chemistry's role in meeting our collective global goals of building a circular economy.

DowDuPont Specialty Products; www.dow-dupont.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.007

Evonik to sell methacrylates business

Chemicals company Evonik says that it has signed an agreement to sell its methacrylates business to private equity firm Advent International for €3 billion. Methacrylates are common monomers in polymer plastics, and Evonik's methacrylates business has 18 production sites and 3,900 employees worldwide. From 2016 to 2018, the business generated an average annual EBITDA of about €350 million and sales of about €1.8 billion per year.

The transaction includes the company's methacrylates, acrylic products and CyPlus business lines, and some of its methacrylate resins activities.

Evonik says that this divestment is part of its strategy of focusing on specialty chemicals, which are less cyclical.

Evonik; www.evonik.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.008

Release agent manufacture in Brazil

Florence Chemical Industry (FCI), the Latin American subsidiary of UK company Marbocote, says that it has completed one year of semi-permanent composite release agents manufacture in Brazil.

Located in São Paulo, FCI's production unit has an installed capacity of two million liters/year, a potential that should be increased by the end of 2019, according to Ana Clara Cordeiro, company's sales director.

'With the expansion of sales to the rubber and composites segments, plus the soon entry into the areas of friction and polyurethane, everything indicates that we will expand our capacity in the coming months,' she said. 'We have invested in the construction of a state-of-the-art laboratory structure, which gives us full support so that we can adjust the release agents according to the needs presented.'

In all, FCI manufactures 40 types of semi-permanent release agents, all of which are free of silicone.

Marbocote; www.marbocote.co.uk

0034-3617/https://doi.org/10.1016/j.repl.2019.06.009

FCI has the capacity to produce two million liters/year of semi-permanent release agents in Brazil.

Gurit CFO to leave the company

Gurit reports that Angelo Quabba, current CFO, will leave the company by September 2019. Quabba joined Gurit in 2015 as a CFO and 'has contributed significantly to the development of Gurit over the past four years,' the company said in a press release. 'By the end of September 2019 Angelo will leave Gurit in best mutual consent and pursue another professional opportunity.'

Gurit; www.gurit.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.010

Hexagon completed financing package

Hexagon Composites says that it has successfully completed a NOK 1.6 billion financing package with the aim to promote further organic growth.

Development will focus on hydrogen opportunities and new market development, according to the company.

'All of Hexagon's businesses are addressing energy related opportunities and are benefiting from increased focus on lower carbon emissions,' the company said in a press release. 'The ongoing push towards a cleaner and safer energy future is driving strong market growth.'

'With the recent acquisitions of Agility Fuel Solutions and Digital Wave, Hexagon has become an even stronger force in driving the energy transformation towards cleaner energy sources,' said David Bandele, CFO of Hexagon.

Hexagon Composites; www.hexagongroup.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.011

Hexcel and Arkema open R&D lab

Hexcel and Arkema say that they will open a joint research and development laboratory in Les Avenières, France.

This follows the companies' formation of a strategic alliance to develop thermoplastic composite solutions for the aerospace sector, combining Hexcel's carbon fiber and Arkema's polyetherketoneketone (PEKK). The aim of the new lab is to develop carbon fiber-reinforced thermoplastic prepreg tapes to make more lightweight parts for aerospace with faster production cycle, the companies say.

The companies expect to start supplying carbon/thermoplastic UD tapes to customers for evaluation in Q3 2019.

Hexcel; www.hexcel.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.012

Johns Manville appoints new president

Composites specialist Johns Manville (JM) has appointed John Vasuta as the new president of the company's Engineered Products business.

The business covers glass fiber nonwovens, polyester spunbonds and glass fibers for the building and construction industry, as well as for automotive, industrial and residential applications.

'John is an accomplished leader and a welcome addition to JM's leadership team,' said Mary Rhinehart, JM's president and CEO. 'He brings to JM a proven track record of successfully growing businesses and global commercial leadership.'

Composites specialist Johns Manville (JM) has appointed John Vasuta as the new president of the company's Engineered Products business.

Vasuta most recently worked at Bridgestone Corp as president and managing director, firestone building products international.

'Johns Manville is built on a rich history and has a well-earned reputation as a global market leader,' he said. 'I am excited to join the company and to lead the Engineered Products business.'

Johns Manville; www.jm.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.013

Chemistry finalists announced

Nouryon (formerly AkzoNobel Specialty Chemicals) has announced the 13 finalists for the 2019 edition of its Imagine Chemistry collaborative innovation challenge.

According to the company, the competition was launched to tackle chemistry-related challenges, and the 2019 edition attracted more than 160 ideas from startups, scale-ups, university spin-outs, and other potential partners. Winners are granted awards ranging from joint development and research agreements to support from partners.

'I'm impressed by the quality of submissions and the ideas of this year's finalists are highly interesting,' said AB Ghosh, managing director Surface Chemistry at Nouryon. 'I'm looking forward to see who we'll be working with to help drive sustainable growth in the future.'

Nouryon; www.nouryon.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.014

The competition was launched to tackle chemistry-related challenges.

Ethical win for Owens Corning

For the second consecutive year, glass fiber specialist Owens Corning has been recognized by the Ethisphere Institute as one of the world's most ethical companies in 2019.

The Ethisphere Institute, which focuses on the standards of ethical business practices, recognized Owens Corning as one of four companies in the construction and building materials industry.

'We're honored to be included again on the Ethisphere Institute's distinguished list,' said Ava Harter, Owens Corning general counsel. 'For Owens Corning employees, this is an important recognition of our ongoing commitment to integrity and the highest standards of conduct in everything we do.'

Owens Corning; www.owenscorning.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.015

Fiber placement center acquires more partners

SGL Carbon and Fraunhofer IGCV have acquired two new partners to their Fiber Placement Center (FPC), established by in Meitingen, Germany.

Cevotec, a fiber patch placement specialist aims to set up a pro prepreg processing line by mid-2020, while Coriolis plans to expand its Coriolis C1 robot-based fiber placement system.

'The Fiber Patch Placement process is particularly suitable for complex shaped components while achieving short cycle times,' said Thorsten Gröne, managing director of Cevotec. 'Through joint projects in the FPC, we will further develop our technology and create new applications together with our partners.'

The FPC has over 500 m^2 of lab space with different machine making it possible to develop production concepts and demonstrate their feasibility by prototyping.

SGL; www.sglcarbon.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.016

Sabic joins Netherlands composites group

Thermoplastic specialist Sabic says that it has recently become a member of CompositesNL as part of its aim to develop the composites industry in The Netherlands.

CompositesNL covers the manufacture, maintenance and reuse of products that use composite technology with a special focus on sustainability and recycling.

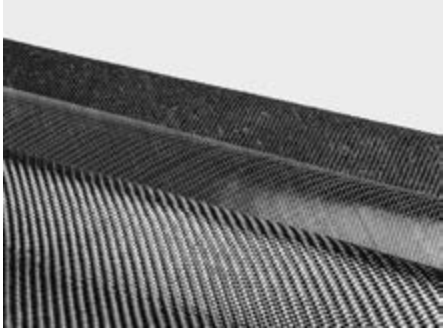
'The Netherlands is a country that has an extensive value chain, stimulates competencies in thermoplastic composites, and is willing to invest in innovation,' said Gino Francato, global business leader, advanced composites, Sabic.

Sabic; www.sabic.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.017

Partnership between NCC and SGL Carbon

The UK's National Composites Centre (NCC) and SGL Carbon have entered into a new partnership to develop composite technologies for different applications in aerospace, transportation and oil & gas. The partnership will focus on material utilization for primary and secondary structure components.



The companies plan to set up a development program for the processing of carbon fiber-based textiles such as non-crimp fabrics (NCF) at the NCC's research and technology facility in Bristol. Over the course of this year, they will produce demonstrator components and prototypes of new composite airplane wings using NCF materials based on carbon fibers from SGL Carbon.

'The NCC is a highly experienced partner driving future composite concepts, especially in the aerospace industry,' said Andreas Wüllner, president at SGL Carbon. 'With the partnership, we generate knowhow around efficient usage of composite materials and technologies.'

SGL Carbon; www.sglcarbon.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.018

Solvay and Safran sign long term supply agreement

Solvay has signed a long-term agreement with Safran for the supply of high temperature composites and adhesives. Safran will use these materials on several of its engine components.

This new contract, in addition to the supply agreement for the LEAP Engine signed in July 2018, further extends and reinforces the companies' collaboration, they say.

Solvay; www.solvay.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.019

TenCate Advanced Composites changes name

TenCate Advanced Composites, part of the Toray Group, has change its name to Toray Advanced Composites. TenCate Performance Composites, a subsidiary of TenCate Advanced Composites, will be changed to Toray PMC.

Toray, a global supplier of carbon fiber and composite materials, acquired TenCate Advanced Composites in 2018, and has been working in recent months to integrate them into the Toray Group.

'We are excited to transition into the Toray family and continue to provide the best value to our customers under our new identity,' said Keisuke Ishii, CEO of Toray Advanced Composites.

Toray Advanced Composites; www.toraytac.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.020

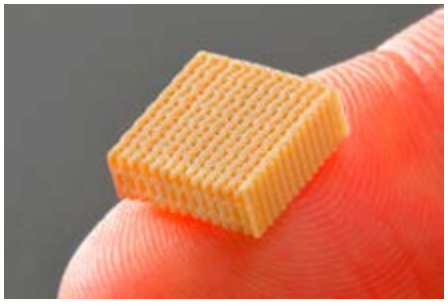
Victrex invests in 3D printing

UK-based chemicals company Victrex says that it has invested in a Dutch 3D printing company.

Bond High Performance 3D Technology has developed a range of 3D printing machinery and software which can produce parts from existing thermoplastic grades.

'Our investment in Bond's 3D technology is a logical way to accelerate 3D printed PAEK/PEEK parts to market,' said Jakob Sigurdsson, Victrex CEO.

Victrex and Bond say that they will initially focus on developing parts in the semiconductor segment using commercially available products and say that functional parts from existing PEEK grades may also have value in aerospace, energy, automotive, manufacturing and engineering applications.



Victrex and Bond say that they will initially focus on developing parts in the semiconductor segment.

Victrex; www.victrex.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.021

DSM acquires specialty materials business

Royal DSM has reportedly reached an agreement with Indian chemicals company SRF Ltd to acquire its engineering plastics business for INR3.2 billion (around €38 million).

DSM says that the acquisition conforms to its strategic aim of generating positions in fast-growing economies. SRF's engineering plastics business was founded in 1979 and its main operations are located in the city of Pantnagar. It realized sales of about US$37 million in 2018.

In 2018, DSM's total sales in India, realized with about 550 employees, amounted to about €250 million, an increase of 17% compared to 2017, the company said.

DSM; www.dsm.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.022

Gurit acquires PET recycling facility

Gurit's newly formed company Gurit Italy PET Recycling has signed an agreement to acquire a polyethylene terephthalate (PET) recycling production facility from Italian company Valplastic for an undisclosed purchase price.

'Gurit has and will continue to invest significantly into recycled PET core material production assets globally for wind and non-wind industry customers to cope with the material demand,' the company said in a press release. 'In order to have sufficient feedstock of quality controlled and properly blended PET for the extrusion process, Gurit needs to have good access to this part of the value chain.'

Valplastic specializes in the recycling of PET bottles and the production of recycled PET-flakes and granules later used for extrusion of recycled PET core.

Gurit; www.gurit.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.023

Focus on up-cycling composite by-products

Hexcel has joined forces with a Lyons, France-based startup that develops material sourced entirely from carbon composite by-products generated by the aerospace sector.

Lavoisier Composites's Carbonium material has been developed with a process based on three patents pending and can reportedly reduceoverall environmental impact by 40–50%, compared to equivalent products derived from virgin materials. A cycle assessment carried out with Hexcel showed that the up-cycling of by-products from the aerospace composites industry could lead to a reduction in CO_2 emissions of 13 kg per kg of Carbonium used.

Hexcel; www.hexcel.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.024

Financials

Our roundup of composites-related financial reports over the last two months

Chemicals company **BASF** had a 3% increase in sales to €16.2 billion for Q1 2019.

EBIT before special items was €1.7 billion, a decrease of 24% (€549) million year on year. According to the company, this earnings decline was primarily due to lower contributions from its Materials and Chemicals segments.

'In these segments, we had exceptionally high isocyanates margins and strong cracker margins in the first quarter of the previous year,' said Dr Martin Brudermüller, chairman of the board.

Market demand

Gurit said that its Q1 net sales grew 54.9% to CHF 142.7 million from Q1 2018 figures.

Composite Materials achieved net sales of CHF 53.5 million CHF for same period, an increase of 6.5%, while the company's Wind business grew by 13.1% across all core material categories and in particular in polyethylene terephthalate (PET) and balsa. Gurit saw a strong market demand in Q1/2019 which is expected to continue throughout 2019.

Sales to other material markets decreased by 2.9% within which Marine grew mid-single digit while sales to Industrial markets sales were off to a slow start in 2019, the company said.

Kitting recorded solid sales of 34.4 million CHF in Q1/2019 but as the business has reported results only as of Q4 2018 within Gurit there is no comparison to the first quarter of 2018.

Tooling had a net sales growth of 45.9% to CHF 36.1 million while aerospace revenues saw a growth of 8.4% to CHF 14.3 million due to solid demand in Europe and growing demand in the US business, Gurit says. Composite Components had a 12.4% growth to CHF 4.5 million.

Sales growth

Hexcel Corporation reported a sales increase of almost 13% for Q1 2019.

Sales for the first quarter of 2019 were US$609.9 million, an increase of 12.9% compared to the first quarter of 2018. Commercial Aerospace sales of US$415.5 million increased 8.6% for Q1 2019 as compared to the prior year period, while Space and Defense sales of US$107.8 million increased 19.6%. Total Industrial sales of US$86.6 million for the first quarter of 2019 increased 28.7%, while wind energy sales, the largest sub-market in Industrial, increased 78%.

'Hexcel generated its highest ever quarterly sales with growth across all of our markets, and our diluted earnings per share increased by over 23% compared to Q1 2018,' said Nick Stanage, CEO. 'With strong sales growth and most of the headwinds that challenged us in 2018 now behind us, margins have stepped up year over year as we forecasted. Reflecting robust revenue growth in the period there was a US$15 million use of cash in the first quarter related to working capital, in line with expectations. The integration of our latest acquisition, ARC Technologies, continues on track with strong first quarter performance.'

Operational execution

Glass fiber specialist **Owens Corning** published consolidated net sales of US $1.7 billion in first-quarter 2019, a slight decrease of 1% versus 2018.

First-quarter 2019 net earnings attributable to Owens Corning were US$44 million, compared with US$92 million, in Q1 2018.

The company said that decline was primarily in the company's roofing and insulation businesses, driven by lower sales and production volumes, and that the results of the composites business were comparable with last year, with execution and volume growth largely offsetting cost inflation.

In April 2019, Brian Chambers succeeded Mike Thaman as CEO of the company. 'I am honored to be leading Owens Corning as the company's eighth CEO,' said Chambers. 'We are excited about the opportunity to drive growth across our global product portfolio to create value for our shareholders. For the first quarter, our results reflect good operational execution across the company.'

Owens Corning said that in composites, the company continues to expect growth in the glass fiber market, although the global industrial production growth outlook has softened, primarily in Europe.

Strong performance

Chemicals giant **SABIC** said that it received a net profit income of SR 3.41 billion in Q1 of 2019, an increase of 5% compared to SR 3.24 billion posted in the previous quarter.

Total sales during the first quarter amounted to SR 37.37 billion, a decrease of 7% compared to the same quarter of the previous year, and a decrease of 11% against the previous quarter.

SABIC says that the change in Q1 2019, compared to the same quarter of 2018, was due to slowing demand growth coupled with a slow year start and a relatively high level of inventories.

'SABIC has demonstrated strength and resiliency in our financial performance under challenging market conditions,' said Yousef Al-Benyan, SABIC vice chairman and CEO. 'Though lower petrochemical prices negatively impacted SABIC's first quarter results, we continued to deliver strong operational performance, including the highest quarterly sales volumes over the last four quarters.

'Sustainability is a key focus for SABIC,' he added. 'At the end of last year, and in support of the circular economy, we have signed a Memorandum of Understanding (MoU) on recycled petrochemical feedstock in Europe with Plastic Energy, a UK-based company. Since then, we reached another significant milestone in the production of certified circular polymers using a feedstock produced from mixed plastic waste.

SABIC is also one of the 27 founding members of 'The Alliance to End Plastic Waste', which is a global initiative between major plastics makers and some consumer goods makers.

High production

Aerospace composites company **Spirit AeroSystems** reported Q1 revenues of US$2.0 billion, up 13% from the same period of last year (Fig. 1).

This increase was primarily driven by higher production volumes on the Boeing 737 and 787 programs, favorable model mix on the Boeing 737 program and higher revenue recognized on the Boeing 787 program, the company said.

FIG. 1

Spirit AeroSystems had planned to increase production to 57 aircraft per month on the Boeing 737 program.

The Fuselage Systems segment's revenue in Q1 2019 increased by 11% from the same period last year to US$1.1 billion, while Propulsion Systems segment revenue increased 23% from the same period last year to US$486 million. Wing Systems' revenue increased 8% from the same period last year to US$408 million, primarily due to higher production volume on the Boeing 737, 777 and 787 programs as well as higher wing deliveries on the Airbus A350 program.

'Previously, we had planned to increase production to 57 aircraft per month on the Boeing 737 program beginning in approximately June 2019,' said Tom Gentile, president and CEO. 'Now, we will be maintaining production at our current rate of 52 aircraft per month. With this schedule, we will produce fewer 737 MAX aircraft this year than we previously forecasted, by five units per month beginning in June, for as long as we remain at a production rate of 52 aircraft per month.

'Given the reduction in production units and corresponding revenue, we have begun taking immediate actions to reduce expenses, defer capital investments, and redouble our efforts on working capital improvements to mitigate the financial impact of the production rate change. After spending US$75 million in the first quarter on share repurchases, we will pause our share repurchases pending further clarity surrounding the 737 MAX.'

BASF; www.basf.com
Gurit; www.gurit.com
Hexcel; www.hexcel.com
Owens Corning; www.owenscorning. com
SABIC; www.sabic.com
Spirit Aerosystems; www.spiritaero.com

0034-3617/https://doi.org/10.1016/j.repl.2019.05.006

ELSEVIER

Technology

New composite materials from Huntsman

Huntsman Advanced Materials has launched four new products in its range of adhesives and composites systems.

For the aerospace market the company has developed Epocast 1648 and Epocast 1649-1 edge and void fillers for aircraft interior construction. Both products offer low density, fast cure and meet flame, smoke and toxicity (FST) requirements, Huntsman said. The materials can be used for potting, ditch potting, edge filling and the reinforcement of honeycomb structures. Epocast 1648 has a compressive strength of 7,250 psi (49.9 MPa) which makes it suitable for utilization in higher load applications, while Epocast 1649-1 has an easy-to use mix ratio and a 12-month shelf life.

Huntsman says that it has also introduced a new acrylate product range for extreme conditions. Araldite 2050 and Araldite 2051 structural adhesives can reportedly speed up bonding operations in sub-zero temperatures, and in saltwater or high humidity conditions.

Araldite 2050 is a fast curing, two-part acrylate designed to accelerate the structural bonding of thermoplastics, composites and metals at temperatures from −20 to 25 °C (−4 to 77 °F) without additional heat, while Araldite 2051 is a fast curing, two-part acrylate that has improved toughness and resilience to vibrations, impact and dynamic loading at temperatures from 0 to 40 °C without additional heat.

Huntsman Corporation; www.huntsman.com

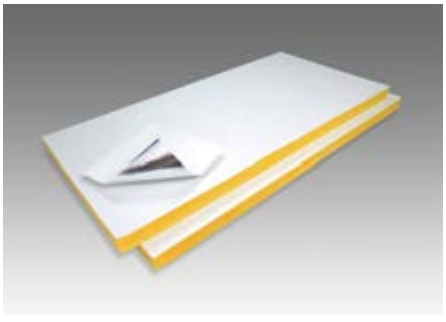
0034-3617/https://doi.org/10.1016/j.repl.2019.06.051

Glass fiber insulation has polypropylene facing

Johns Manville has developed 800 Series Spin-Glas Ultra, a glass fiber insulation board with a polypropylene (PP) coated (poly-top) facing.

According to the company, the PP coating allows the board to be wiped down for better cleanability.

'Most facings used on mechanical insulation have a kraft paper component, but the new facing we are using on our 800 Series Spin-Glas Ultra board has no paper,' said Meredith Westerdale, Johns Manville's mechanical product manager. 'We've found that for fiberglass boards, this can improve their wrinkle-resistance,' she said.



800 Series Spin-Glas Ultra is a glass fiber insulation board with a polypropylene (PP) coated (poly-top) facing.

800 Series Spin-Glas Ultra can be used on any ASJ specification as it meets the requirements of a polymeric film type ASJ per the NIA Glossary. Additionally, it meets the highest rating for low permeance vapor retarders as a Type I classified material per ASTM 1136, the company says.

Johns Manville; www.jm.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.052

Silver conductive epoxy adhesive

Master Bond has developed a new one part, silver filled epoxy adhesive that is not premixed and frozen and reportedly has an unlimited working life at room temperature.

Master Bond Supreme 3HTS-80 is a volume resistivity of less than 0.05 ohm-cm which exhibits a hardness of 50–60 Shore D and a high thermal conductivity on curing. The company says that the 100% reactive epoxy bonds well to metals, composites, glass, ceramics, and many plastics. It can also withstand thermal cycling and shock with a service operating temperature range from −100 °F to +350 °F (−73 °C to +177 °C).

'While typical heat activated epoxies require 250 °F–350 °F to cure, Supreme 3HTS-80 cures at 175 °F–185 °F within 2–3 hours,' said Rohit Ramnath, senior product engineer. 'Curing at such temperatures makes this system advantageous for bonding applications involving heat sensitive substrates.'

Master Bond; www.master-bond.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.053

Water-based carbon fiber sizing

Michelman says that it has launched a new carbon fiber sizing product, as part of the company's Hydrosize water-based range.

Hydrosize Carbon allows carbon fiber manufacturers to improve the interfacial adhesion between the polymers and the fibers by tailoring the surface chemistry of their reinforcement fibers to the chemistry of the matrix resin.

The Hydrosize Carbon 200 Series has been designed for polyamides including high-temperature application. It is alkyl phenol ethoxylate (APE), solvent, and volatile organic compound (VOC)-free and is suitable for fiber reinforced nylon composites where greater thermal stability is required.

The 300 Series has been formulated for polycarbonates (PC) and other PC blends such as PC- acrylonitrile butadiene styrene (ABS), and reportedly has improved chemical resistance and interfacial adhesion to polymer systems. Applications include laptop cases or other electronic components.

Michelman says that it has launched a new carbon fiber sizing product.

The Hydrosize Carbon 400 Series includes grades that can withstand more extreme processing temperatures and can work with materials include polyarylethereterketone (PEEK), polyphenylene sulfide (PPS), polyethylenimine (PEI) to produce various composite engine components. It is suitable for use with chopped carbon fiber applications.

Michelman's Carbon 700 Series has been designed to improve the performance of carbon fiber reinforced vinyl ester composites and is suitable for under-the-hood applications. It can provide increased adhesion between the carbon fiber and various vinyl ester compounds.

Michelman; www.michelman.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.054

Large scale resin infusion

The National Composites Centre (NCC) in the UK and Composite Integration Ltd have completed a year-long project to design and deliver large scale resin infusion (LSRI) technology suitable for research and development in the aerospace and wind industry markets where components can range from 17 m up to 120 m in length.

The £36.7 million covers digital manufacturing technologies being installed at the NCC to support composites innovation, manufacturing and research development programs across a range of sectors.

The liquid composite molding (LCM) process, one of the core competencies of the NCC, is used to produce composite parts with better integrity, without the need for an autoclave. Using LCM fibers can be first assembled 'dry' into a mold, resin is then pumped into the fibers and drawn through under vacuum prior to being cured in an oven.

The first application of the technology will be to enable infusion of complete wing components, the NCC says. The new process is now available to companies across the UK, can inject high resin volumes into a variety of preforms, primarily, but not limited to, using a vacuum bagged set up.

The machine can also process both single or two-part resin systems and can be used with a 20 m oven to enable cure of those resins.

The machine can also process both single or two-part resin systems and can be used with a 20 m oven to enable cure of those resins.

Larger batches

'Processing aerospace grade epoxy resin systems at elevated temperatures brings with it a number of challenges,' said Simon Vincent, design and engineering manager at Composite Integration. 'Although equipment exists on the market for processing smaller quantities of these resin systems, as the scale of aerospace parts being manufactured using liquid resin infusion has increased, there was an evident need to develop machinery capable of processing up to 400 kg of high temperature epoxy resin. This is the first machine of its kind that can process this type of resin in batches larger than 50 kg.'

NCC; www.nccuk.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.055

Peroxide for composite processing

Nouryon (formerly AkzoNobel Specialty Chemicals) has introduced a new version of its Butanox M-50 Vanishing Red peroxide for the composites market. The new version contains a less-hazardous dye solvent that makes it safer for to handle when curing unsaturated polyester resins, and reduces its environmental impact, the company says.

'Customers using automated dosing equipment may face problems if peroxide doesn't properly flow through the dosing line, leading to under-cured or uncured end products,' said Raymond ten Broeke, polymer chemistry customer support engineer at Nouryon. 'This can be very costly to manufacturers if molds need to be cleaned. Using Vanishing Red peroxides helps prevent such failures without leaving a trace that any indicator was used.'

Nouryon; www.nouryon.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.056

PostProcess expands 3D post printing technology

PostProcess Technologies, which focuses on the finishing of 3D printed parts, has developed a new system to help support structure and resin removal.

PostProcess Technologies, which focuses on the finishing of 3D printed parts, has developed a new system to help support structure and resin removal on 3D printed PolyJet, fused deposition modeling (FDM), stereolithography (SLA) and continuous liquid interface production (CLIP) parts.

The Forti system's submersed vortex cavitation (SVC) technology reportedly makes use of ultrasonics, heat and fluid flow along with additive formulated chemistry. It features a pumping scheme to create vortex action to improve the rate of removal of the support material and minimize buoyancy issues.

PostProcess has also released the next generation of its Rador automated surface finishing system, which it says can customize agitation levels and improve process cycles to achieve the desired Ra (roughness average) for a range of 3D printed materials.

PostProcess; www.postprocess.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.057

IFR appoints Dr Susanne Bieller as general secretary

The International Federation of Robotics (IFR) has reportedly appointed Dr Susanne Bieller as new General Secretary. Dr Bieller will take over from Gudrun Litzenberger, who is retiring. Litzenberger will also hand over the management of the IFR Statistical Department to D. Christopher Müller.

'As an 'ambassador of robotics', I am looking forward to supporting the dynamic development of robotics and continue IFR's successful work in future,' said Dr Bieller. 'One of my focus tasks will be to ensure a better understanding of the complex industry issues around the globe.'

Dr Bieller has been project manager of the European Robotics Association EUnited Robotics for five years and began her professional career as MD of the flat-panel display group at the German Engineering Federation (VDMA).

The International Federation of Robotics (IFR) has reportedly appointed Dr Susanne Bieller as new General Secretary.

Dr Müller is head of the IFR Statistical Department and responsible for worldwide industry data and analyses. The IFR represents more than 50 manufacturers of industrial robots and national robot associations from over twenty countries and was founded in 1987 as a non-profit organization.

The International Federation of Robotics; www.ifr.org

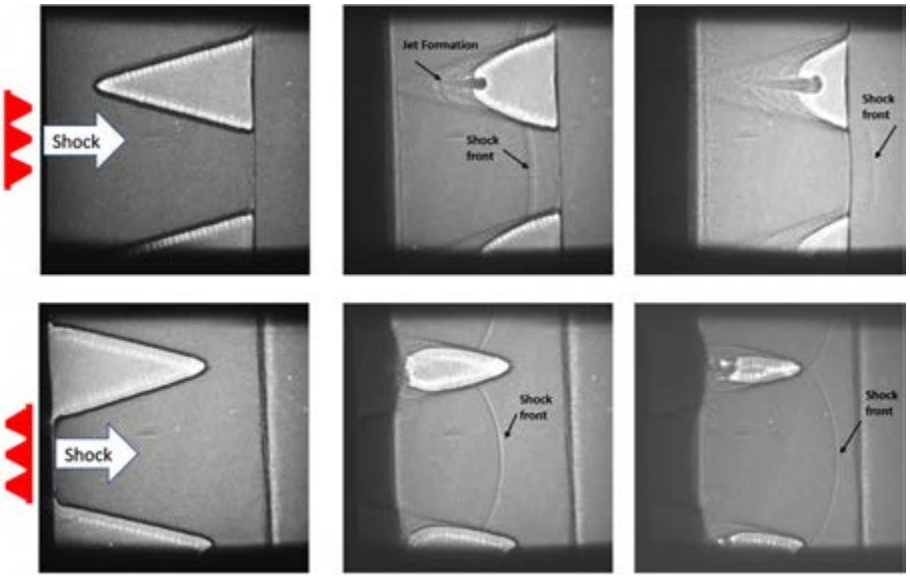
0034-3617/https://doi.org/10.1016/j.repl.2019.06.058

3D printed polymer can localize shocks

The US Air Force Research Laboratory and research partners at Los Alamos National Laboratory have reportedly developed a 3D printed polymer-based foam structure that can respond to the force of a shock wave to act as a one-way switch, a long sought-after goal in shock research.

According to AFRL senior materials research engineer Dr. Jonathan Spowart, this new material configuration, although in the early stages of development, could be scaled up in order to be used in different ways for a variety of applications, including for the protection of structures.

The material is a foam-like structure that contains a series of specifically-engineered tiny holes that determine the overall behavioral characteristics. Scientists used computer modeling to run trials to determine the most effective hole geometries to achieve the desired material response. According to Spowart, the end product can be described as containing a series of hollow cones. When these cones encounter a shock wave, they collapse inward, forming jet protrusions that project from the opposite side, and these jets localize the shock wave energy, the scientists say.



The 3D printed polymer-based foam structure can respond to the force of a shock wave to act as a one-way switch, a long sought-after goal in shock research.

US Air Force Research Laboratory; www.afresearchlab.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.059

Solvay launches release film for the wind industry

Solvay has introduced VAC-PERF A2400, a release film for wind energy applications.

VAC-PERF A2400 is reportedly compatibility with a range of resin systems from polyesters to next-gen epoxies and is a suitable alternative to legacy release films which have now reached their performance limits, Solvay says.

The film has maximized release properties, a simplified peeling off process, clean laminate and usage flexibility so that it can be used for resin infusion and prepreg cures.

It is available in width of up to 2 m and can lowers kitting costs with a 20% reduced assembly time capability, the company adds.

Solvay; www.solvay.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.060

Partnership focuses on improving tape layup

The companies have tested using automated fiber placement (AFP) process with Victrex' AE 250 UDT for aerospace applications.

Victrex and Coriolis Composites have formed a partnership to improve thermoplastic unidirectional tape (TP UDT) prepreg lay-up and consolidation and improve the manufacturing efficiency of composite parts.

The companies have tested using automated fiber placement (AFP) process with Victrex' AE 250 UDT for aerospace applications.

The results of the study show improved lay down speed at acceptable porosity levels for TP UD laminates and can compete with automated fiber placement/automated tape laying (AFP/ATL) deposition rates for thermosets without the necessary lengthy autoclave consolidation time required for thermoset UDT (TS UDT).

'We developed a set of conditions that demonstrated time and energy savings, indicating the potential benefits of the deployment of AE 250 UDT composites for large scale structural aircraft parts,' said Dr Justin Merotte, composites project engineer at Coriolis Composites.

Victrex; www.victrex.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.061

Solvay announces AM competition winners

Solvay has revealed the winners of its AM Cup 2019, a competition for university students around the world to 3D print specific shapes using the company's Radel polyphenylsulfone (PPSU) AM filament.

Each team received a spool of the filament and was asked to replicate an ASTM D638 Type V size tensile bar in the z-axis and a wavy-shaped pressure pipe, a difficult shape to injection mold. The teams aimed to achieve dimensional accuracy and mechanical performance, including burst pressure tests, and translucency. In addition, the jury evaluated the creativity of the 3D printing methods.

The overall winner was the Gekko Performance team from the Technical University of Munich, Germany. The team achieved 100% z-axis strength in the Type V size tensile bar and its wavy pipe showed overall dimensional accuracy, surface uniformity, and an improved mechanical performance by enduring a burst pressure test of 1,400 psi (96.5 bar) for two hours.

Each team was asked to replicate an ASTM D638 Type V size tensile bar in the z-axis and a wavy-shaped pressure pipe.

Two teams from Ghent University, Belgium – PPSUsual and PPSUPER – were awarded second and third place respectively.

'It was inspiring to see the various approaches to solving the challenges of fused filament fabrication (FFF) such as bed adhesion and chamber temperature management. The winning team demonstrated once more that 3D printed parts can virtually match the performance and quality of conventional injection molded parts, provided material, hardware, and process are optimised together,' said Ryan Hammonds, R&D platform manager at Solvay's and president of the jury.

Solvay; www.solvay.com

0034-3617/https://doi.org/10.1016/j.repl.2019.06.062

ELSEVIER

INTERVIEW

Cellulose promises a low-carbon future for composites - an interview with Steve Eichhorn

Cordelia Sealy

Far from aiming for a 'paperless' society, Steve Eichhorn, Professor in Materials Science and Engineering at the University of Bristol, believes cellulose could hold the key to a sustainable, low-carbon future.

Composites are widely used in a diverse array of applications wherever a combination of mechanical strength and lightweight is needed. But composites typically rely on petrochemical-derived resins reinforced with carbon or other inorganic materials that are neither low-carbon nor sustainable to produce.

But, Eichhorn, who has dedicated his career to understanding cellulose, is convinced that composites based on natural, sustainable materials – particularly cellulose – can replace current petrochemical-derived materials without impacting on the environment.

His interest in cellulose began with an M.Sc. and Ph.D. in papermaking at Bangor University and UMIST in Manchester. He stayed in Manchester as a research scientist and lecturer, before moving to the University of Exeter in 2011, where he led the Engineering Department from 2014-2017. Now with a research group in Bristol, he is pursuing the development of renewable, sustainable composite materials based on cellulose.

Steve Eichhorn of the Cellulose and Renewable Materials Group talked to Reinforced Plastics about his current research and future plans.

What are the major themes of your current research?

I have been working on cellulose, which is a plant material, for the last 20+ years. Most recently I've focused on what we call nanocellulose, which are fibers smaller than 100 nm extracted from plants chemically or mechanically, as reinforcement for composite materials. We are also trying to find ways to spin high-performance, novel cellulose fibers from ionic liquids [1].

We are also looking at gels, which are basically these fibers concentrated in water. Many of the creams and shampoos we use, as well as some of our foodstuffs like ketchups and mayonnaises, contain gels, known as 'rheological modifiers, which give food texture and creams or shampoos the ability to spread on the skin or hair, hold fragrances, and improve the cleaning process. We would like to make these gels in different ways using less energy.

Recently, we've been moving more towards functional materials, where we use cellulose as the base of a material or device that has a particular function. For example, replacing the use of inks in plastics with films that are colored because of their structure [2]. We are also exploring ways of making materials magnetic by including magnetic nanoparticles in the structure, which could be useful as actuators [3]. We've also been looking at energy storage applications, where we convert the material to an all carbon-form that is conductive but also has a very high surface area, which could be suitable as electrodes in supercapacitors [4].

How and why did you come to work in these areas?

I studied physics as a first degree, but then did a Masters in paper science and forestry industries technology. I got really interested in cellulose at that point and did my PhD on the material. I realized that there are a whole range of things you can do with cellulose, which is the most widely used material in the world, and that there are many opportunities, particularly in sustainable applications. What really sparked my interest was the work of others and the possibilities of replacing oil-based polymers with cellulose. That captured my imagination.

What do you think has been your most influential work to date?

I think there are two. One is a piece of work we did a long time ago to work out the stiffness, or Young's modulus, of tunicate cellulose nanocrystals, which are made by a type of marine organism [5]. We were the first group to establish the mechanical properties of this highly crystalline form of cellulose. From that initial work we were able to establish a fundamental understanding of the physical properties of nanocrystalline cellulose or nanocellulose. This work really started us off on the road we are on now, trying to make and understand nanocomposites.

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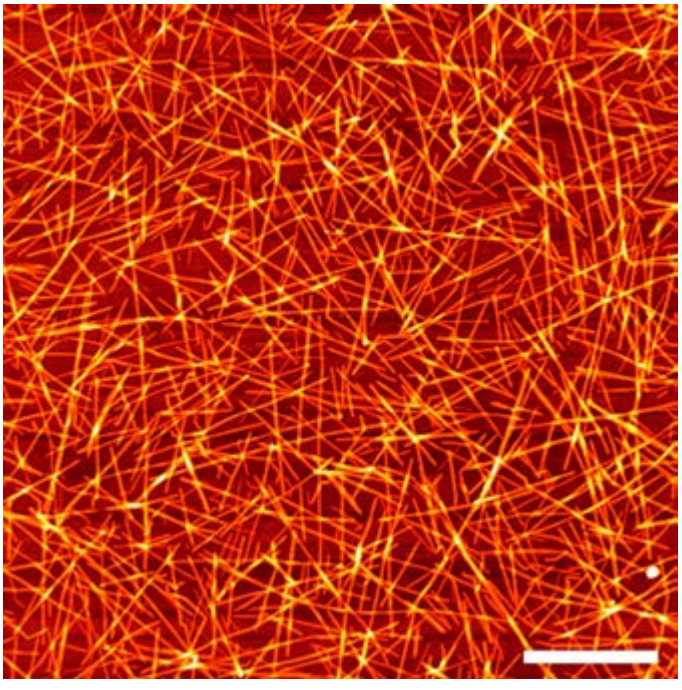

An atomic force microscope image of cellulose nanocrystals extracted from tunicates. Scale bar is 1 micron.

The Cellulose and Renewable Materials Group on an outing to Bristol Botanical Gardens. (Back row, left to right: Muhammad Ichwan, Dr Marcus Johns, Kate Oliver; bottom row, left to right: Eileen Atieno, Jing Wang, Dr Panjasila Payakaniti, Chenchen Zhu, Anna Taylor, and Steve Eichhorn.)

The other piece of work that I am very proud of was done with a former colleague, Bill Sampson, at the University of Manchester [6]. We were both paper scientists at the time and we noticed that there were synergies between the structures of electrospun fibers, which were novel at the time, and paper fiber structures. We applied mathematical models, which Bill had developed, to electrospun fiber networks and were able to show quite clearly that rather than making smaller fibers for tissue engineering, thicker fibers were better for creating larger pores into which cells could infiltrate. This had, I think, a big impact on tissue engineering in the early days, particularly for producing artificial skin. It demonstrated how one area of specialism can have a major influence on another.

What is the relevance of your research to fiber-reinforced composites?

Cellulose is a lightweight material and has specific mechanical properties that are comparable to glass fibers. So using plant fibers to replace glass is quite an interesting area of research.

But if you reduce the length-scale, to nanocellulose, the number of defects within the material is reduced. This is a burgeoning area of research at the moment. In Japan, for example, the car manufacturer Toyota is seriously considering nanocellulose-based composite materials for car bodywork, while Ford is exploring similar plans in the US.

In our work, we look for ways to make new fibers and how those fibers disperse in resins to build up a picture of how these materials form, their structures, and what the barriers are to getting the best performance out of these new composite materials.

What have been the most major developments in this field over the past decade in your opinion?

The ability to process nanocellulose with thermoplastics has been a major development. Cellulose is hydrophilic, so it doesn't like to interact with hydrophobic materials like thermoplastics. There have been huge inroads made in being able to injection mold, with thermoplastics, some of these materials on larger scales.

Where do you see this area of research going in the future?

I think that one area where there will be major developments is in terms of large-scale, high-volume applications. But there are also an awful lot of low-volume, high-tech applications of nanocellulose on the horizon in areas such as medical diagnostics and energy storage materials. The idea of making a lab-on-a-sheet-of-paper that is able to diagnose common illnesses could have a major impact in the developing world.

In terms of other global-impacting technologies, I believe water purification systems will benefit greatly from nanocellulose-based filtration media that can capture viruses.

Although plants produce nanocellulose naturally, it is very difficult to make in the lab. In the future, it will become increasingly important to harness enzymes and bacteria that can produce cellulose as well as regular polysaccharide materials.

Nanocellulose and natural fibers are highly functionalizable in a myriad of ways. Because they possess a large number of hydroxyl groups, they have a very reactive surface to which we can tag or attach other molecules. This is not a feature readily available with many other polymer types.

And, of course, the main advantage of nanocellulose and natural fibers is that they are renewable! If we use more cellulose in the future, we will have to maintain and grow forests and plants, which are both sustainable and sequester carbon dioxide. The use of cellulose could be a significant contributor to excess carbon reduction by acting as a sink for carbon dioxide. We urgently need to move away from our reliance on oil-based materials towards more sustainable materials that can go back to the environment without causing harm. Cellulose is one such opportunity for us. We used to be very reliant on cellulose and I think we need to go back to that reliance on renewable materials.

Are there any developments that you would particularly like to see come to pass?

If we understood more about the plant cell wall, and the interactions that occur inside plant cells, we might be able to extract cellulose more cheaply and efficiently. I believe that would have a huge impact on our use of cellulose.

What factors do you believe will be key to the success of the field in the future?

Funding is key to keeping this field alive. I wish more people would get involved in cellulose research in the UK and elsewhere. We need industrial take up of materials for large-scale, large-volume applications and we need small-scale, high-tech end-users to come through to the market. Governments could also do more to push sustainable materials, to insist that we don't use harmful persistent polymers in applications.

What specific questions or problems do you hope to tackle in the future?

I plan to go back to basics. I want to understand the interaction of cellulose with water: water plays a huge role in the interaction of sugars and influences molecular structure but very little is known about its influence on the molecular structure of cellulose.

But I am also going to start looking at how cellulose helps influence the properties of interfaces in composites and delamination toughness in larger structures.

My work in the future will range from fundamentals to applications.

What is the secret to successful research?

Diversity is really important. I've been very lucky to have a very diverse group over the years: everyone contributes and brings different strengths. As a group leader, I think it's important to understand where people have come from, their background, and how best to help them develop, learn new skills, and contribute to knowledge. We all collaborate together, sharing techniques and expertise with materials. With diversity, come different ideas. If I surrounded myself with people who looked and thought like me, it really wouldn't work!

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ELSEVIER

FEATURE

New innovations in automotive thermoplastics

Liz Nickels

A recent JEC innovation award winner was a set of glass fiber thermoplastic sunroof guide rails. For the first time, glass fiber thermoplastic sunroof guide rails could replace a similar set made in aluminum. This new application could lead to big things for the automotive composites industry.

Polyscope, based in the Netherlands, is a company that produces a range of materials, including styrene maleic anhydride (SMA) copolymers, compounds, aqueous solutions and styrene, maleic anhydride and N-phenylmaleimide (SMANPMI) terpolymers.

It also makes SMA/ABS-based compounds with a range of impact modification and glass fiber loading levels. For other applications, low-molecular weight Xiran-based resins are available.

Recently the company won a JEC's innovation award for its manufacture of thermoplastic composite guide rails for a car sunroof in the automotive application category (Figure 1).

This partnership project involved the Polyscope team working with automaker Groupe Renault, automotive roof systems manufacturer Webasto SC and specialist toolmaker and molder AARK-Shapers, all based in France.

Polyscope's Xiran SGH30EB, a 15% glass-reinforced copolymer compound of styrene maleic anhydride and acrylonitrile butadiene styrene (SMA-GF), was chosen by Webasto France and Renault to make the roller-blind guide rails on a set of panoramic sunroof modules installed in Renault's Scenic (five-seater) and Grand Scenic (seven-seater) multipurpose vehicle (MPV) models.

Bond strength

The formulation was developed by Polyscope to help ensure high bond strength with the polyurethane adhesive used to mount the glass to the module and the module to the body-in-white (BIW) roof structure, instead of the more conventional two or three-step process where rails are fastened with screws to the BIW and the module is then fastened to the rails. A Z-axis element-stack reduction of ≈13 mm could therefore be achieved.

The company also focused on making a material that could be injection molded to make more dimensionally stable parts with a high shot to shot consistency; this could in turn help ensure a smooth opening and closing operation of the roller-blind system. The need to use a lubricating grease on the rail guides was also eliminated.

AARK-Shapers molded eight SMA-GF composite parts in a family tool that also features modular blocks, allowing both the Scenic and Grand Scenic guide rails to be molded in the same tool without using tool moving slides or requiring additional tools. The asymmetric upper and lower thermoplastic rail sections were injection molded in two pieces and then joined after demolding.

At Renault's assembly plant, the redesigned sunroof system arrived fully assembled and pre-tested as a one-piece ready to install unit. The sunroof unit was then robotically bonded to the vehicle roof. As the thermoplastic composite module has fewer parts, Renault could benefit from reduced long-term warranty costs, due to lower parts per million (PPM) defects.

Polyscope says that this is the first time that a thermoplastic composite material has successfully replaced aluminum for this type of sunroof design in a mass-produced passenger car.

'We are absolutely delighted and feel very honored to have won this prestigious JEC Innovation Award,' said Ferdi Faas, business unit director at Polyscope. 'It was a challenging application development for the Polyscope team, but we were fortunate to be working with outstanding, highly technical, design and engineering people in Webasto France and Groupe Renault and the specialist partner companies involved in this project.'

Thermoplastic benefits

According to the company, the environmental benefit was an important reason for choosing thermoplastic composite for the

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FIGURE 1

From left to right: Henri-Paul Benichou (sales and business development manager) Ferdi Faas (business unit director engineering plastics), Sem Sals (product development engineer), Michel Baseotto (business development manager), Paul van den Heuvel (market and application development manager) and Maarten Camps (Secretary General Ministerie of Economic Affairs and Climate) with the Innovation award at JEC World 2019. (Photo courtesy Polyscope.)

sunroof guide rails. Like aluminum, the SMA/ABS base resin material is fully recyclable, but uses significantly less energy to produce the rails and to recycle them at end of a vehicle's life, due to a fusion temperature difference of 260 °C versus 1,000 °C. Moreover, using thermoplastic composite instead of conventional anodized aluminum extruded profiles freed up 13 mm headspace for passengers and increased the angle of vision through the glass panel. According to Polyscope, the composite guide rails simplified the construction and installation of the sunroof on assembly lines. 'In total, the project delivered a significant system cost reduction for the installed, improved design, panoramic sunroofs,' the company said.

I spoke to Henri-Paul Benichou, sales and business development manager at Polyscope, about the specific benefits of the material. 'SMA-GF is light, stiff and presents very low warpage and low thermal deformation without post-mold crystallization, so molded parts maintain tight tolerances over a broad range of temperatures and humidity levels,' Henri-Paul explained. 'It has a low density and it's easy to weld and recycle.' The maleic anhydride part of SMA is reportedly a key aspect of maintaining a strong bond to a variety of substrate materials, including the polyurethane (PUR) adhesive used to join glass to the sunroof module (Figure 2).

Moreover, 'Xiran SMA-GF lowers noise, vibration and harshness (NVH) and is considered more pleasant sounding when the sunshade is in operation.'

Project beginnings

Henri-Paul next told me about the inspiration for the project. 'Webasto conducted a study designed to evaluate if aluminum guide rails for roller-blind modules could be redesigned in composite and still meet OEM requirements,' he explained. 'The company's main objectives were to increase the space above passengers' heads and the vision through the glass panel.

'One proviso was that rails should permit easy sliding of the motorized shade along the track. As a result, they required a constant geometry over a length of 1 m or more to help ensure a smooth translation from front to back or from left to right sides.

'The rails also need a solid connection to other module components, including front and rear cross-beams, motor mechanism, vehicle roof structure, glass, and headliner,' he said. 'To glue composite rails to a glass panel also requires precise curved shape with very tight tolerances. Additionally, the rails must operate at a low level of sliding noise when the shade is closed or opened.'

Henri-Paul explained why this application had not been attempted before. 'This is most likely because aluminum guide rails were considered too difficult to be made of composite in such a technical application.' (Figure 1)

Previous success

Webasto investigated several materials at the initial stage of the project, he went on the say. Thermosets were ruled out due to their high density, long molding cycles, post-mold finishing and possible volatile organic compounds (VOC) issues. 'Moreover, they cannot be welded or easily recycled. Thermoplastics such as polyamide (PA), polybutylene terephthalate (PBT) and polyethylene terephthalate (PET) were also eliminated due to the risk of warpage, as well as their limited accuracy and dimensional variations.'

He noted that Webasto had already used Xiran SMA-GF to make sunroof frames, so it was natural for them to focus on using the same thermoplastic composite for sunroof roller-blind rails. This was back in 2013, when Polyscope worked with the

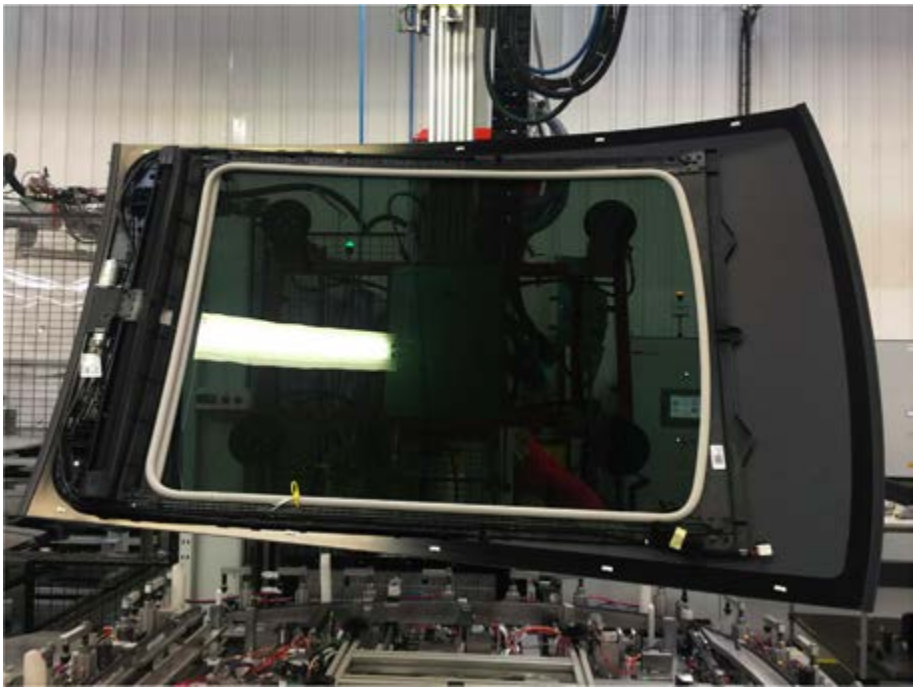

FIGURE 2

The sunroof module arriving at Renault's assembly plant fully assembled and pretested as a one-piece ready to install unit to be robotically bonded to the vehicle roof. (Photo courtesy Polyscope.)

FIGURE 3

The thermoplastic sunroof frame for the Citroen DS3 Cabrio. (Photo courtesy Polyscope.)

company to develop the frame, made for the Citroën DS3 Cabrio vehicle. It was injection molded in a Xiran glass reinforced blend of styrene maleic anhydride (SMA) and ABS developed by Polyscope (Figure 3).

At the SPE Central Europe Automotive Awards that year, the frame won third prize. 'Weight reduction and extended functionality are two key drivers throughout the automotive industry, and as a long-term partner to the industry, Polyscope is pleased to be recognized for the significant work done in this critical area,' said Patrick Muezers, MD of Polyscope, at the time. 'New projects are under development in SMA-based materials with the goal to reduce even more weight, include even more functionality, and further reduce part count on sunroof systems.' (Figure 2)

Better vision

I asked Henri-Paul about how this application could pay off for automotive manufacturers.

'The total system cost reduction is significant,' Henri-Paul said. 'Additionally, the switch from aluminum to composite rails enabled more working space for assembly-line workers and, above all, more headspace and better vision for vehicle occupants.'

Henri-Paul considers that composites – particularly thermoplastic composites – have a significant potential for growth in automotive applications. 'With recognized benefits like weight saving and high function integration, they will help electrical and/or autonomous vehicles to improve their operating range and optimize their design,' he said. 'For cost reasons, the major growth in automotive is expected to come from hybrid structures, in which short fiber thermoplastic composites such as Xiran SMA can be combined with metal or local unidirectional (UD) fiber reinforcements in the form of organosheets or tapes.'

What about the potential of glass fiber? 'Glass fiber reinforced composites are much less costly that carbon fiber materials and will remain for a long time,' he affirms. 'Although carbon fiber materials allow more weight saving and higher stiffness than glass fiber composites, the automotive industry limits its usage to rather small volume applications due to the critical cost premium.'

Key strengths

Polyscope is continuing to work with a range of automotive OEMs and composite molders. 'Similar parts are already under evaluation or development for upcoming vehicles,' said Henri-Paul. However, 'Polyscope currently has no plans to develop similar parts for the aerospace industry as the property profile of our current thermoplastic Xiran SMA composite material does not fit the technical requirements. However, we are active with our SMA

resins for thermoset composite applications in the aerospace industry.'

The next 20 years will be key for the company, and the use of SMAs in general, he foresaw. 'We plan to further strengthen Polyscope's position as a true SMA powerhouse, building on the key properties of SMA: dimensional stability and functionality,' said Henri-Paul. 'We are applying these strengths of SMA to an increasing number of polymers, such as polypropylene (PP), high impact polystyrene (HIPS), PA6 and polymethyl methacrylate (PMMA), and for a continuously growing variety of applications in the automotive, medical, electronics, and packaging industries. It is our plan to keep on discovering the full potential of SMA together with our partners from the industry.' (Figure 3).

Polyscope; www.polyscope.eu

ELSEVIER

Orthotropic steel deck renovation: An examination of the hybrid GRP sandwich underlay

FEATURE

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Introduction

Steel decks are mainly used in bridges where concrete decks result in too much dead weight: in both decks for long fixed bridges and for movable bridges. In traffic bridges, steel decks are often built as welded orthotropic decks according to Fig. 1 (left side).

At the end of the last century it was found that many of the orthotropic steel bridge decks showed signs of fatigue due to the increase of traffic intensity in general and the use of super single wheels for trucks in particular (also view Fig. 1). Orthotropic steel decks generally consist of a deck plate of 12 mm thickness at a minimum, and typically every 300 mm is supported by webs of bended _/-shape steel plate ribs, which are welded underneath the deck plate [1].

Currently, the most applied solution to fatigue is an in-situ overlay with high strength concrete (HSC), replacing the asphalt layers. For decks with only a thin epoxy/grit wearing surface layer, this results in a heavier and higher deck, which is a considerable disadvantage when it comes to movable bridges [2].

As an alternative, an underlay of the steel deck plate consisting of a foam core and a glass-fiber reinforced polymer (GRP) bottom plate was studied, as a potential solution for obtaining the same weight and height. The hybrid sandwich replaces the _/-ribs. The foam core creates a smooth uniform distributed support for the steel deck plate instead of the concentrated line supports, see Fig. 2.

This alternative solution comes with a couple of challenges:

- work has to be carried out overhead because of the in-situ renovation underneath the existing bridge deck
- bulging of the steel deck plate will have to be prevented when the _/-ribs are removed
- the sandwich panels need to be bonded to the deck plate without air inclusions, as local delamination might grow under cyclic wheel loads (fatigue)
- falling cargo on the repaired deck should not lead to local delamination between the steel deck plate and bonded polymer foam core. Also view Fig. 3.

Falling cargo

The effects of falling cargo were studied first because this is most important limiting factor for new hybrid sandwiches consisting of steel plate – foam core – GRP plate. Rijkswaterstaat (RWS), the Dutch Department of Infrastructure, prescribes that bridge decks should be able to resist an impact of a falling steel object with a cone-diameter of 0.15 m and 50 kg from a drop height of 1.3 m without damage.

A program was set up to test the impact resistance of a sandwich construction consisting of 12 mm S235 steel plates of 1×1 m^2 on the bottom covered with a resin layer, placed on 0.2 m layer of foam core material, see Fig. 4. As resin, Vinyl ester (Atlac® 430, AOC Aliancys) and Epoxy (RIMR135, Hexion) were used with and without flow medium glass veil (Viledon T 1777) or glass CSM (M123 Chopped Strand Mat). As supporting foam core either PS (Styrodur 2800C, 30 kg/m^3) or PVC (Airex C70.90, 100 kg/m^3) was used with and without rigid edge supports.

Damage occurred in the layer of bonding resin between the steel deck plate and foam core in the range of 0.8–1.2 m drop height when the bonding resin was fiber reinforced.

When non-reinforced, the resin layer showed cracks in combination with small dents in the steel plate in the range of 1.5–1.6 m drop height. In none of the test cases, damage was observed in the foam core.

The use of the stiffer (PVC) foam and rigid edge supports gave cracks in the layer of bonding resin at the lowest drop heights within the above ranges.

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It was concluded that the RWS requirements for falling cargo can be met with a non-reinforced interface under a 12 mm steel plate. Furthermore, dents in the steel plate can function as a warning signal for possible delamination caused by a larger impact than described by RWS.

Fully wetted interface under steel plate

The next experiments were needed to show the possibility of getting a fully wetted interface under the steel deck plate without a flow medium in the bonding layer. To be able to visually check the wetting during the experiments, the steel plate was replaced by a glass plate. Both hand lamination and vacuum infusion were considered. It was decided that if vacuum infusion proved possible, this process would be preferable because it is more industrial and less dependent on good workmanship to prevent the formation of air pockets.

In the experiments, a length of 1 m resin flow was tested under glass at a width of 0.1 m. The applied resin was again Atlac 430. With flat core panels full wetting was only achieved by using flow medium.

Therefore, two groove patterns in the core were tested. Grooves of b = 21 mm and d_{max} = 1 mm and of b = 28 mm and d_{max} = 2 mm were cut into the core with a circular saw, with the grooves gradually building up in steps of b = 3.5 mm and Δd = 0.5 mm. Both groove patterns are shown in Fig. 5.

The ends of the panels were cut with cross grooves of b = 3.5 mm at the maximum depths, which is shown in Fig. 6. Both groove patterns resulted in full wetting without air inclusions. In Fig. 6 the grooved brown foam cores are shown as well as the flat green foam cores with white flow medium during infusion.

It was concluded that by applying grooved cores full wetting can be achieved by vacuum infusion without the use of a flow medium.

Hybrid sandwich dimensions

As the next step the design of a steel deck was used to be redesigned as a hybrid GRP sandwich underlay. The deck plate in this particular design was 12 mm thick and covered with an epoxy layer of 5 mm, sprinkled with grit as a rough wearing surface. It contained steel cross beams lying 3 m center to center and in between the cross beams _/-shaped t = 5 mm steel plate ribs were welded towards the deck plate with their webs every 300 mm, at a height of 300 mm and a span of 3 m. The height of the sandwich was chosen the same as the steel plate ribs: 300 mm. This was to keep the connection at the bridge deck ends intact (see A in Fig. 7).

A FEM analysis of the bridge deck under Eurocode loads was carried out to obtain design section forces. It appeared that a GRP layer of 6 mm as a bottom flange, with a fiber volume content of 50% and with fibers distributed in 0/90° directions (respectively 50/50%) was easily capable of resisting the stresses both static and under fatigue. The GRP bottom flange at the cross beams (the Bs in Fig. 6), which were put under compression only, was already able to handle the pressure based on the resin alone. All compressed flanges were checked for local buckling: the support of the 100 kg/m^3 core appeared more than enough.

The steel deck plate stress comprises two contributions due the wheel loads of 0.4 × 0.4 m^2 on the deck: first the local bending stress in the deck plate on the core bed and secondly the global bending stress in the deck sandwich between the cross beams. The global bending stress range due to longitudinal moment was calculated to be 16 N/mm^2. The local bending stress range

FIGURE 1

Orthotropic steel deck (left) and fatigue cracks: in deck plate above webs (middle) and in welds along webs (right).

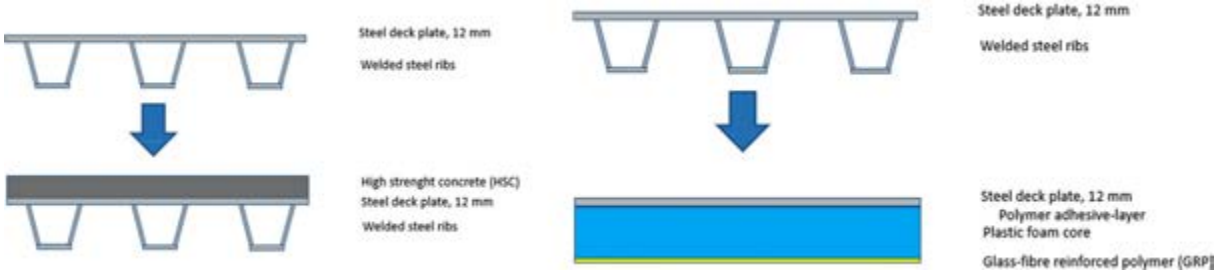

FIGURE 2

Steel deck renovation: HSC overlay (left) and GRP sandwich underlay/replacement (right).

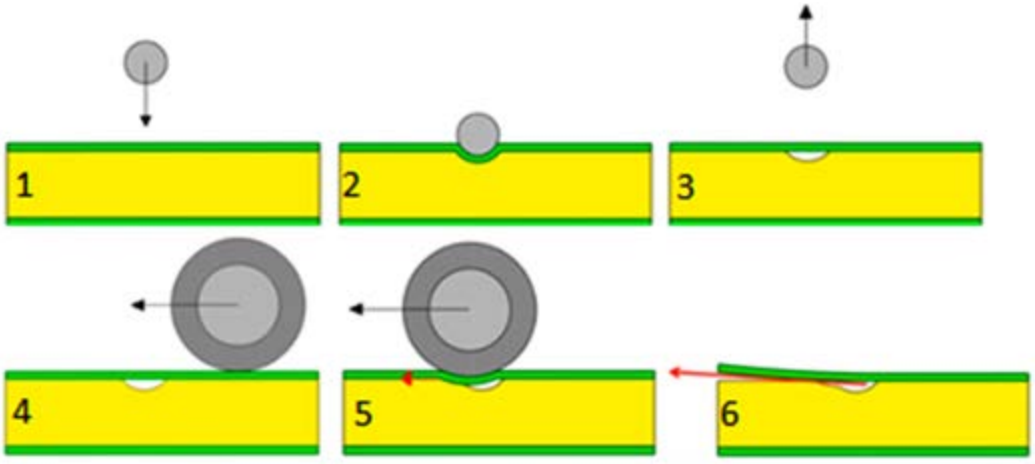

FIGURE 3

Falling cargo risk: creating local delamination (1–3) and growing delamination (4–6).

FIGURE 4

Impact experiment: set up, cone, clamped sample and the impact damage on the resin layer.

FIGURE 5

Tested groove patterns in the top side of the core.

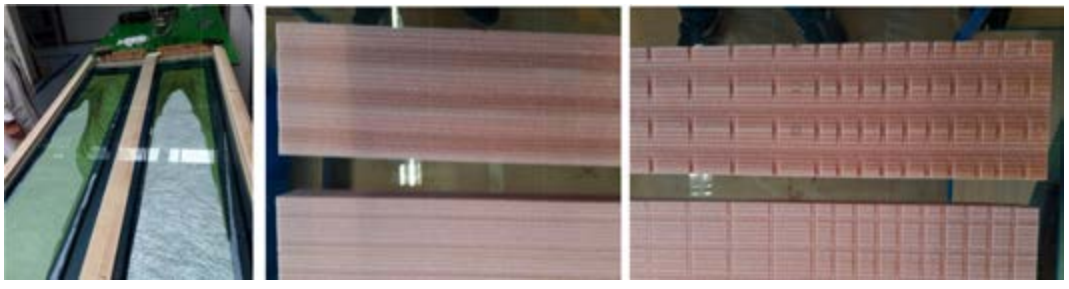

FIGURE 6

Wetting experiments on flat green core with flow medium and on grooved brown cores only.

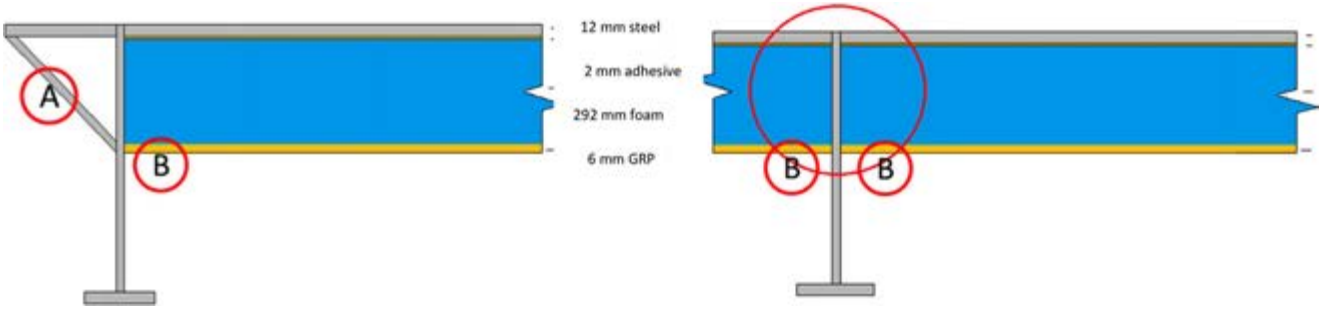

FIGURE 7

Hybrid sandwich–bridge deck connections: at end respectively, intermediate cross-beams.

due to spreading the wheel load in the deck over the whole sandwich, came to 8 N/mm^2. The combined stress range $\Delta\sigma$ of 24 N/mm^2 remained below the fatigue cut-off limit of 29 N/mm^2. Consequently, no further contribution to the cumulative damage is expected, which is the purpose of the GRP sandwich underlay.

The shear capacity of the bonding resin and the steel interface appeared not to be decisive. From the calculations it appeared that the PVC foam core (100 kg/m^3, h = 292 mm) can only just resist the statically design shear stress of 1.25 N/mm^2. For a remaining lifetime of 100 years the fatigue design stress of 0.56 N/mm^2 becomes decisive and requires a somewhat higher foam density for Europe's busiest roads.

With these dimensions, approximately the same weight can be obtained as in the present situation.

Implementation plan: step by step

In the reference case, _/-shape steel plate ribs were applied in four successive spans of 3.0 meters in between five cross beams to the deck of L = 12.6 m. Over a deck width of B = 27.6 m, in between two deck side ribs and next to three main beams, four fields of _/-ribs were present of which 2 × 5 adjacent ribs were located under the truck lanes.

Several specialists (RWS, steel manufacturer) have assessed that, without tests, it is only safe to remove and replace one

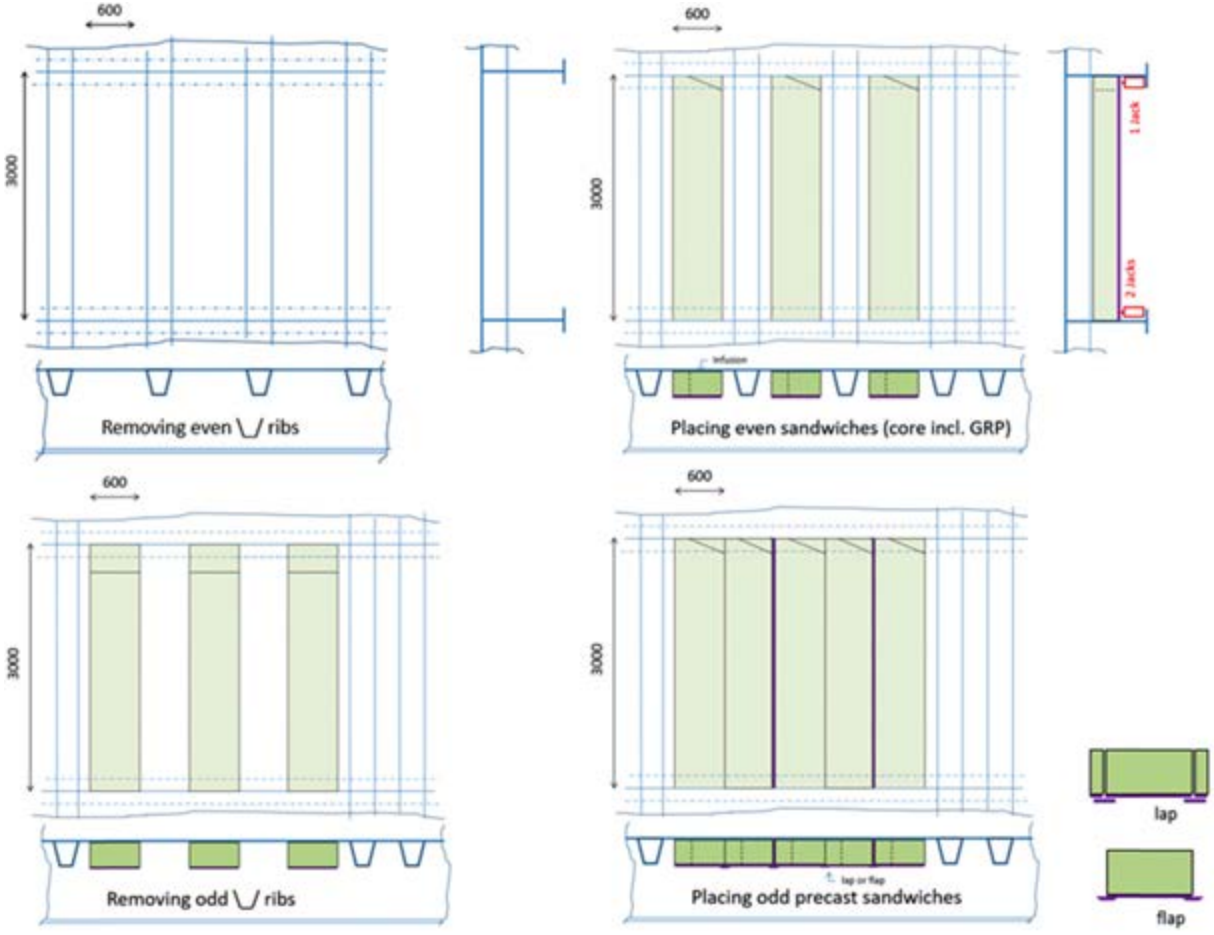

FIGURE 8

Replacement plan of _/-ribs working from a cherry picker lift on a pontoon.

row of successive _/-ribs at a time. In the implementation plan per truck lane therefore first the three even rows are replaced and then the rows in between, see Fig. 8.

Working from a cherry picker lift on a pontoon under the bridge the following step by step implementation is foreseen:

- the bottom side of the deck first needs to be plane grinded, grit blasted and cleaned
- the precast sandwich element (core + GRP bottom flange) is then brought in under the deck and turned into position above the under flanges of the cross beams
- the element is pushed up by three jackscrews standing on the bottom flanges of the cross beams and kept in place by inserting a wedge core
- the element is then wrapped up in vacuum foil, which will be connected air tight to the deck plate
- using tubes, the resin is brought in under vacuum between the steel deck plate and grooved sandwich core.

It is recommended to first test the above plan on a removed deck in a realistic pilot project setup. It is then also possible to remove more than one adjacent row of ribs at the time, for instance over the full width of a truck lane, to check if bulging of the deck plate will occur.

Economic feasibility

For a movable highway bridge of L = 12.6 m and B = 27.6 m the economic feasibility was assessed based on both direct and indirect costs.

The indirect costs are expected to be in favor of the hybrid sandwich variant, as the sandwich underlay/replacement is kept to two small widths of the truck lanes whereas the concrete overlay needs to be executed per half bridge deck. The traffic hinderance in case of the sandwich variant is consequently smaller in width and furthermore expected to last a shorter period of time.

The direct costs are also expected to be in favour of the hybrid sandwich variant, although only marginally, as only the trucks lanes have to be replaced by expensive sandwiches versus a concrete overlay being placed over the full width of the bridge deck and in addition extra counterweight by steel: for the added counterweight the starting point is to be kept in a small volume. The financial risk of a yet unknown construction method is expected to be of the same magnitude as the financial risks involved in strengthening the main bridge beams, the machine and the foundation of the weighted bridge.

Acknowledgments

This paper is an extended version of the graduation research projects of three civil engineering students. The research was conducted with the guidance of the companies *Fiberneering* and *AOC Aliancys*, and the professorship of *Polymer Engineering* of Windesheim University of Applied Sciences (UoAS). The study was funded by the Centre of Expertise GreenPAC. A network of private and public parties provided the practical information. Fig. 1 was made available by Rijkswaterstaat (RWS) and Fig. 3 by the courtesy of Fibercore.

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ELSEVIER

FEATURE

Biocomposites take natural step forward

Mark Holmes

Applications for biocomposites and the use of natural fiber reinforcements are increasing. *Reinforced Plastics* looks at a number of examples.

The market for biocomposites – plastic or bioplastic containing natural fibers and nanofibers as reinforcement – continues to grow in thermoset and thermoplastic composite applications. Sustainability issues are a major factor with material suppliers, manufacturers and end-user brand owners wanting to highlight their environmental credentials. However, reducing weight and costs is also a consideration. Biocomposites and natural fiber reinforcements are now available from a number of sources.

Composites Evolution is a developer, manufacturer and supplier of prepregs and natural fiber reinforcements for the production of lightweight structures from composite materials. At the *Advanced Engineering Show* held in late 2018 in Birmingham, UK, the company highlighted a lightweight composite train seating cantilever support, manufactured using a fire-retardant bio-based prepreg (Figure 1). The project was undertaken in collaboration with Bercella and Element Materials Technology (Element).

The component, which is 1 m long but weighs less than 5 kg, passed a wide range of tests performed by Element. The evaluation included static loadings, fatigue cycles and fire testing to EN 45545 according to the requirements of Bercella's customers. Cantilever seat supports, which are mounted on the wall of a train carriage rather than the floor, offer a number of advantages including improved access for cleaning and luggage storage. The lightweight composite structure also provides advantages in terms of reduced train energy consumption and lower axle loads.

The seat support was manufactured by Bercella using Composites Evolution's Evopreg PFC prepreg with a high strength carbon fiber reinforcement. Evopreg PFC was specified for this application because of its good fire performance, low toxicity and good environmental credentials – the base polyfurfuryl alcohol resin is 100% bio-derived. Evopreg PFC is one of the first prepregs to be manufactured on Composites Evolution's new prepreg line that was installed in July 2018.

Composites Evolution's bio-resin Evopreg PFC502 prepreg has also recently completed an extensive series of tests to demonstrate compliance with the Hazard Level 3 (HL3) requirements of rail industry fire standard EN45545-2 (Figure 2). HL3 represents the most stringent requirement of EN45545-2, allowing materials to be used on trains that pass through tunnels where no side evacuation is possible, such as in many underground metro systems.

Evopreg PFC502 prepregs are a range of fire-retardant pre-impregnated composite materials based on a polyfurfuryl alcohol (PFA) bio-resin. PFA is a thermosetting bio-resin derived from crop waste. It is similar to phenolic resin but with lower toxicity and VOC emissions. In addition to its environmental credentials, it has good fire retardant properties, plus temperature and chemical resistance. Evopreg PFC502 prepregs can be used to produce a wide range of interior components including wall and ceiling panels, seats, tables and vestibule areas.

The EN45545-2 testing was performed by Element against Requirement Sets R1 (interior surfaces) and R6 (passenger seat shells). The testing included heat release to ISO 5660-1, lateral flame spread to EN 5658-2 and smoke density and toxicity to EN ISO 5659-2. Both glass and carbon-reinforced PFA laminates were tested and both met the HL3 requirement.

Evopreg PFC502 prepregs can be supplied with a wide range of reinforcement fibers and fabric constructions. They can be consolidated by vacuum bagging, press molding or autoclave and are designed for applications including rail interiors, aircraft interiors, marine, offshore and construction.

Composites Evolution has also developed a hybrid composite tooling system that utilizes the benefits of flax fiber reinforcements to reduce the cost of carbon-epoxy mold tools (Figure 3). The company says that currently, when molding carbon fiber composites in an autoclave, it is common practice to also make

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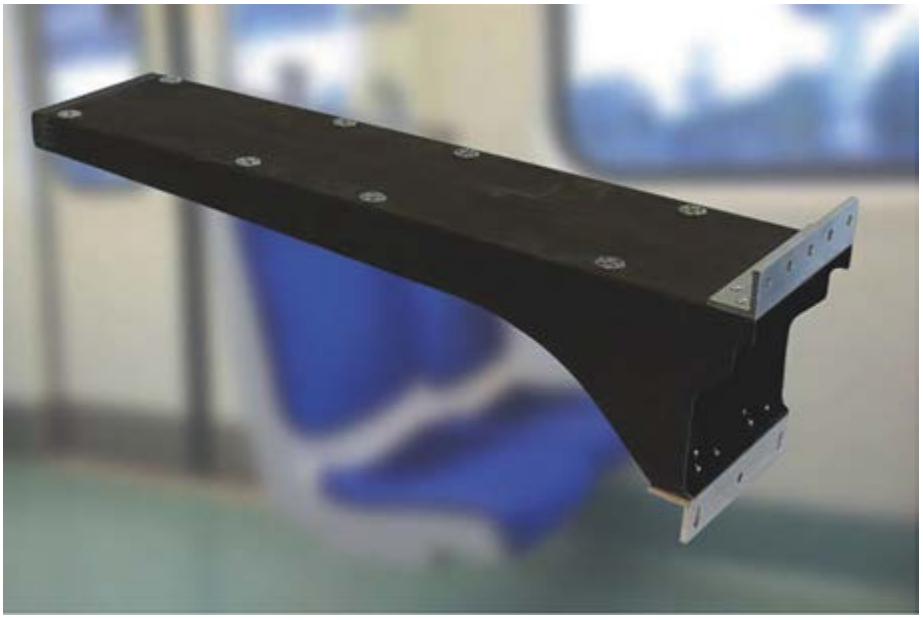

FIGURE 1

A lightweight rail passenger seat support manufactured from a fire-resistant bio-resin prepreg. The seat support was designed and manufactured by Bercella using materials supplied by Composites Evolution. Extensive testing of the structure was performed by Element Materials Technology.

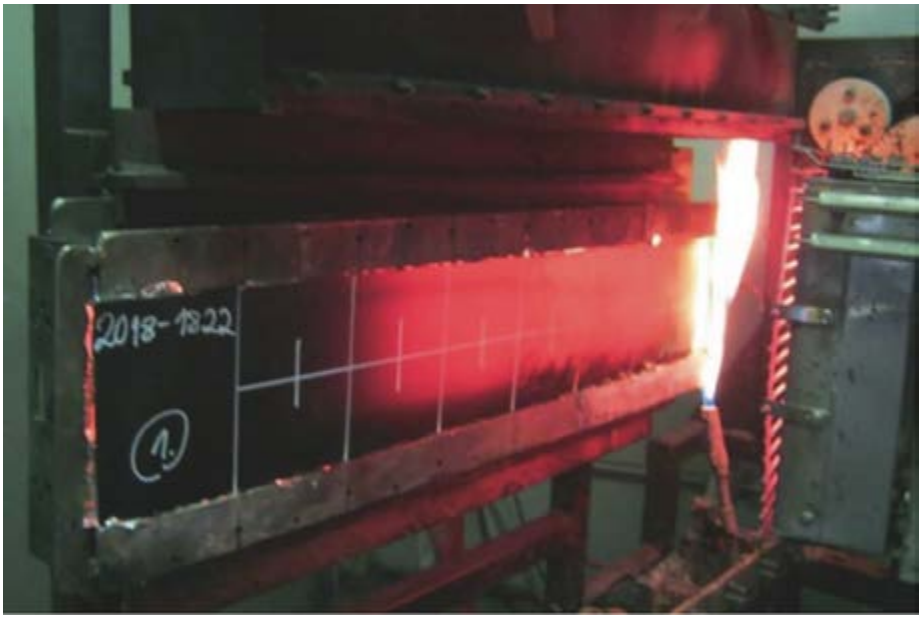

FIGURE 2

Composites Evolution's bio-resin Evopreg PFC502 prepreg has completed an extensive series of tests to demonstrate compliance with the Hazard Level 3 (HL3) requirements of rail industry fire standard EN45545-2.

the tools from carbon fiber prepregs. This ensures that there are no significant differences in the thermal expansion of the tool and the component being molded that might introduce unwanted distortion. However, this also means that the tooling tends to be relatively expensive.

Working in partnership with molders KS Composites, Composites Evolution has developed a new tooling prepreg system based on a hybrid combination of carbon and flax reinforcements. Currently, a standard all-carbon tool might consist of a number of heavier weight bulking plies sandwiched between lower weight outer surface plies. In the new hybrid tooling system, several of the carbon bulking plies are replaced with more cost-effective flax. It is possible to do this because the thermal expansion properties of flax fibers are sufficiently similar to those of carbon. The result is a hybrid carbon-flax tool in which the material costs are reduced by up to 15% in comparison to an all-carbon tool. Secondary benefits include a reduction in tool weight of up to 15% (flax fibers being less dense than carbon

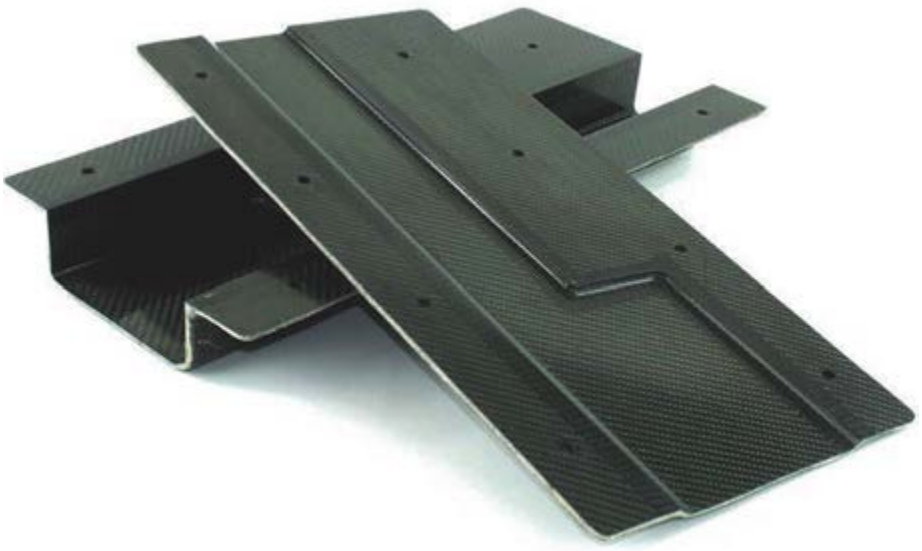

FIGURE 3

Parts made using a hybrid composite tooling system from Composites Evolution that utilizes the benefits of flax fiber reinforcements to reduce the cost of carbon-epoxy mold tools.

fibers) and a reduced environmental impact due to the use of sustainable flax. In trials performed by KS Composites, the hybrid carbon-flax tooling material has successfully completed over 400 thermal cycles. Furthermore, a mold tool manufactured from the system is now used in routine production.

Coventive Composites has been involved with the development of natural fibers for use in plastic composite materials. Long natural fiber thermoplastic, injection moldable pellets are a composite of natural fibers, for example flax, hemp and jute, in a polypropylene matrix. They were developed by Coventive as a cost-effective alternative to long glass fiber thermoplastic (LFT) products in, for example, automotive applications. The company adds that glass fibers are relatively heavy, derived from non-renewable sources and cannot easily be recycled. By contrast, natural fibers are less dense than glass and have a lower environmental impact. They also have a similar stiffness to glass fibers. The pellet format and method by which they are produced also helps to preserve the reinforcing properties of the natural fibers; these are often compromised in other more aggressive compounding processes. The pellets are typically a 50:50 mix by volume of natural fibers and polypropylene fibers. They were produced using Coventive's in-house pilot line at a length of 5–25 mm, depending upon the requirements of the user. The pellets can then be injection molded using standard equipment. Because natural fibers are less abrasive than glass, they also generate less tool wear.

Providing an update at the *Advanced Engineering Show 2018* Coventive Composites highlighted that development work (Eco-LFT) had started out on a variety of continuous, thermoplastic fibers, using the pultrusion process. Pellet production was successful, but the material property results from molded test specimens were initially not as desired. However, in a follow-up project, PELTEC, pilot-scale trials with flax and jute yarns produced pellets, material properties and process data. Using the given process parameters, and without modifying its machinery, a molding company to a Tier 1 supplier produced sample moldings that passed all the Tier 1 supplier's internal tests.

The pultrusion process uses commingled, continuous yarns. Yarns are highly refined products, and therefore embody a lot of added value. This makes the end product (pellets) too expensive for OEMs to consider as an alternative to glass LFTs. So, Coventive Composites, in collaboration with the BioComposites Centre at Bangor University in the UK and furniture manufacturer Orangebox, is developing the Nat-IM process, which uses discontinuous fibers from further upstream in the yarn refinement process; where fiber quality is retained. The pilot line is producing small amounts of jute-PP pellets and work has been on increasing quality and throughput. Nat-IM finishes in spring 2019 with trial quantities for industrial partners to assess.

APM – Automotive Performance Materials is expanding the use of materials made with natural fibers in the automotive sector. The use of natural fibers instead of mineral fillers permit reduced density and injection of thinner parts, with a weight reduction of up to 25%. APM has developed NAFILean, a natural fiber polypropylene material with 20% short fibers. The company says that end-of-life recycling has been validated and it can be separated and valorized in PP recycling, unlike PP with long glass fibers. Density is 0.98 and it can be processed on traditional injection molding machines. The material offers high performance in stiffness and aging for technical plastic parts. Recent applications include the instrument panel and door panels on the new Peugeot 508 (Figure 4) and instrument panel on the Alfa Romeo Giula. On this vehicle, the thin-wall molded part weighs 3.5 kg, representing a saving of 1.05 kg (23%) over a PE-LGF part.

Attis Innovations has developed a new approach to processing natural fibers for use in plastic composites. A proprietary modified organosolv process converts woody biomass into constituent products, including a lignin unlike all others, says the company (Figure 5). This lignin stands in sharp contrast to the historical

FIGURE 4

The instrument panel and door panels on the new Peugeot 508 have been manufactured with NAFILean from APM, a natural fiber polypropylene material with 20% short fibers.

FIGURE 5

Attis Innovations has developed a proprietary modified organosolv process to convert woody biomass into constituent products, including a lignin, for natural fibers for use in plastic composites.

understanding of lignin, as it abandons the stiff, fibrous form in favor of a melt-flowing thermoplastic product. By flowing at temperature, part design limitations are largely stripped away, giving the designer far more flexibility. This melt-flowing product can be inexpensively compatibilized with HDPE, PP and many other polymers efficiently. To date, Attis has successfully compatibilized the lignin to meet the tensile strength, tensile modulus and impact characteristics of unfilled composites effectively with load levels of 15% and 25% in HDPE and PP, respectively. While Attis is actively pursuing multiple channels to increase the value of its lignin product, polymeric addition remains a key arena for future product growth. The biggest value proposition for natural fibers is their ability to stiffen a composite with a lower part weight addition than glass filled composites. This has good value for all transportation applications. Attis Innovations adds that current issues it is working on include increasingly complex geometrics, and improvements to mold and part design that mean less forgiving processing conditions.

One area that Norway-based research organization RISE PFI is currently involved in is the use of agro-forestry side products, where a valuable and under-utilized product is lignin. In addition to cellulose and hemicellulose, lignin is one of the three major components in lignocellulosic biomass. Wood fibers are usually used as reinforcement, but lignin can also be used as a filler and, if modified correctly, as a polymer matrix for biocomposite production. RISE PFI says that this still requires some further research but it is moving in this direction. Presently, most effort for utilizing lignin is in combination with bioplastics such as PLA, but the organization is also exploring routes to use lignin as a thermoplastic material for injection molding and 3D printing, for example (Figure 6). It is looking to reconstruct and mimic wood by utilizing lignin as a matrix reinforced with wood fibers – all from underutilized side products.

RISE PFI is also looking for new routes to use biomass for the production of 100% green and sustainable biocomposite materials, including bioplastics, fiber and nanocellulose. Nanocellulose is also an area where RISE PFI says it has major competence and a library of lignocellulosic fibers and nanofibers for specific biocomposite applications is being developed. In this case – based on a bio- and circular economic strategy – the utilization of agro-industrial side products is seen as most interesting. There is much biomass that could be upgraded and valorized in a better way than burning it as a source of energy, says RISE PFI.

The VTT Technical Research Centre of Finland says that natural fiber composites are now also finding their way into new application areas in consumer goods and furniture, although

FIGURE 6

Biocomposite protection case for a smart phone, made of PLA and lignin and 3D printed at RISE PFI.

volumes are smaller than in construction or automotive where their use is more common. Trends driving new developments in natural fibers and their use in plastics include fashion in construction and furniture, cost and weight reduction in automotive, and new recyclability and biodegradability requirements. There are also new fibers being used, such as hemp, and side products from other industries are also bringing new fibrous materials to plastic composites.

VTT adds that problems requiring new solutions in natural fiber composites include density when compared to actual mechanical properties and moisture sensitivity, which can limit their applications. In addition, the production of long fiber composites, including flax or hemp for example, requires novel treatment techniques for the fibers. Other current areas of development include efficient and affordable refining of natural fibers, as well as new mechanical and chemical pre-treatment

methods for fibers to provide better compatibility with polymers and improved properties.

According to VTT, alternative technologies could also be employed to solve these issues with natural fibers, such as pultrusion or short residence time compounders like radial and conical extruders. VTT has also developed a novel densifying method for fluffy materials, the VTT compacting method, as well as compounding methods for long fibers and plastics. The VTT Modix-technique involves a single screw extruder with hollow rotor member. VTT has also developed a PLA-cellulose composite material suitable for furniture and mono-material composites. In addition, extrusion foamed biocomposite materials combine the stiffness of natural fibers and light weight of foamed plastic. Applications include heat and noise insulation and impact resistance.

Wood-fiber based Woodforce, developed by Crown research institute Scion in New Zealand and licenced to Sonae Arauco, is a natural and sustainable material that produces lightweight polymer composites that can be recycled several times without losing functionality. Scion says that Woodforce is slowly gaining momentum with a number of producers using it to develop specialist, high performance plastics. The institute adds that there is great potential for nanocellulose in composites – whether as fibers or a component of gels or foams, a broad range of

FIGURE 7

Commercially available 3D printing filament containing 10% wood fiber developed by Scion and made by Imagin Plastics.

FIGURE 8

Orthex Group's kitchen utensils made from DuraSense biocomposite from Stora Enso.

applications is foreseen, with nanocellulose reinforcing, lightweighting and replacing petroleum products or controlling moisture, for example.

Nanocellulose is currently sold in water – 97% water/3% NC. Scion says that dewatering and incorporating it into a plastic matrix and creating a good interaction between the two at an industrially relevant scale, is the main challenge. Lignocellulosic fibers are very hydrophilic, while most polymer matrices are hydrophobic. Ongoing work is looking at ways to modify the fibers in a green, sustainable way so that they are compatible with the matrix and can achieve their full reinforcing potential. Scion is also working on the interaction of fibers and biopolymers, such as PLA and PHA. Being able to produce dry and usable nanocellulose would be a big advantage. However, current processes to dry it without the particle fibers/particle aggregating (hornification) are complex and cumbersome.

Scion is also sourcing cellulose from cow feces. The cows that are part of New Zealand's large dairy industry process grass into cellulose and ensure that a constant supply is available. Effluent collected from places such as dairy sheds can be a serious waste

management problem. Work at Scion has found that the right combinations of dairy effluent, additives and bioplastics can produce composites with a range of properties. Dairy effluent/PLA biocomposites, for example, weather and degrade faster than PLA alone, opening up possibilities for biodegradable plastics in primary industry applications. Work is also underway to explore the potential of algae as a source of nanocellulose. Other research is exploring the potential of protein-based nano fibrils. In terms of developing and promoting a circular bioeconomy, work is continuing on utilizing the by-products of primary industry processing, together with bioplastics, to create a new generation of plastic composites (Figure 7).

Stora Enso, the Swedish-Finnish supplier of wood fiber products, says that brand owners are looking for an affordable solution to go green to lower their environmental impact and the carbon footprint of their products. The company has developed DuraSense, a wood fiber-based biocomposite, which can be reprocessed up to seven times without it losing its properties. This is due to strong Nordic wood fibers that behave differently compared to general plastics, which can lose their properties after initial use. The use of natural fibers also offers an outlet for creative reuse. There is the possibility to transform waste, plastic reject or by-products and re-fashion them into usable products. Stora Enso says that DuraSense provides the moldability and flexibility of plastics with the strength and natural feel of wood. The material behaves similarly to plastic; its density is better than even that of bioplastics but is lighter.

Stora Enso adds that it has invested in new capacity to have the largest equipment in Europe to produce wood fiber-based biocomposites, providing the ability to develop the process further and optimize costs. The company has also broadened its biocomposites' raw material base for the milling of large fibers. This means that it will be able to provide a greater choice of technical properties and selection of fibers for biocomposites and offer an attractive price position compared to traditional plastics. This will make it easier for customers to switch from existing material solutions to those based on biocomposites, says the company.

Stora Enso has recently worked with Orthex Group to launch a bio-based kitchen utensil range, including cutting boards and kitchen tools (Figure 8). In addition, Akvila has used DuraSense to replace polystyrene in disposable and multi-use cutlery. Other applications include furniture, consumer goods and logistic solutions. Stora Enso has also developed a biocomposite material suitable for 3D printing, which has been used to manufacture a complex, round window profile. A further application is stable profiles – a solid wood core covered by a biocomposite skin – providing the necessary strength properties to sustain horse kicks and have low maintenance and cleaning requirements.

ELSEVIER

FEATURE

Single-use plastic for composite infusion moulding – No excuse

Alan Harper

Alan Harper Composites Ltd, United Kingdom

The awakening of the public's awareness that single-use plastic is damaging our environment and oceans gathers more belief than world climate change. It has galvanized and established its place firmly in the national consciousness as never before writes UK's Sunday Telegraph writer Jillian Ambrose. That is because unlike "climate change" discussions, plastic waste requires no study and challenged interpretation of centuries of historic records as found in ice cores, rock strata, tree trunk rings and the like. No – single-use plastic is a very new and real phenomenon, a waste problem which has developed within our living memory and has become our number one environmental challenge (Figure 1).

The single-use plastic waste problem is so great that the act of recycling waste has been overwhelmed by sheer volume and complexity of plastic types. A much more radical solution needs to be found and found with a degree of urgency. Our throw away attitude to waste wrappers, packaging and containers must go through a 180-degree direction change meaning that packaging becomes biodegradable and or reusable.

This single-use plastic waste problem also knocks loudly at the door of today's composite moulder. As many have moved away from open mould production methods the surge in closed mould application is now well established and apart from the more costly RTM and LRTM methods Infusion moulding has increased tenfold both for liquid infusion and prepreg in or outside the autoclave. Referred to as vacuum bagging, few give much environmental concern of the hectares of single unsound use of consumable bagging materials which fill waste skips daily (Figure 2).

The growth of reusable vacuum "bagging" has however increased in the last 8 years to the extent that it would be unwise for any composite moulder to discount this clean and very environmental and commercially sound alternative to the single-use consumable bagging approach Figure 1. Of course, there is resistance from the traditional vacuum bagger technician and it is sad to hear qualified engineers reject the reusable approach. This rejection is always on the grounds that, as reusables are made from silicone, their introduction into the moulding shop would jeopardise the production through silicone contamination. This fear appears entirely based upon emotion of the word "silicone" and not on any form of real case history or study. Our approach to this argument is to offer independent test results using x-ray and infrared spectrometry showing no cross contamination of free silicone to the shop environment or moulded part. Furthermore, the anti reusable silicone bag lobby cannot continue to ignore the increasing thousands of moulders now successfully using the system with many costs and quality benefits without any issues of silicone contamination

The number one reason reusable vacuum membrane application is increasing is primarily due to their more favorable economics over not only traditional consumable bagging infusion but in many ways as a cost effective alternative to the Light RTM process.

It is now a well-established fact that the cost of infusion consumable bagging materials added to the cost of the skilled labour employees needed to position and seal them over the dry reinforcement (or prepreg) prior to infusion, proves that the alternative reusable approach pays for itself within 4–7 cycles.

In terms of resin wastage, reusables commonly achieve a staggering 20% plus reduction over the same part made by LRTM. The fact that they are self sealing and need zero maintenance or need any form of release agent is also factored into their considerable production cost saving benefits.

A notable development feature reusables have brought is to simplify and speed up the method of resin input. Many will agree that traditional infusion under conventional vacuum bags is a relatively slow production method, however, reusables have changed all that. It is now perfectly acceptable to dispense the

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FIGURE 1

Over 20 million plastic bottles are single use daily in the UK alone.

FIGURE 2

A waste skip single emptying cost in excess of £800 are a painful reminder which moulding companies have to put up with whilst assuming there is no real alternative.

entire resin shot under the membrane over the reinforcement in one single pouring action. This eliminates the tiresome slow vacuum infusion from a bucket or machine feed system. The result is not only that the operator dispense operation is completed in seconds but also this frees them up for new tasks whilst the infusion takes place automatically. The infusion fill time is dramatically reduced allowing quicker gel and cure bringing faster cycle times.

There are some who voice a note of caution over this new departure of resin dispense suggesting it brings greater air inclusion in the laminate which sounds a reasonable concern. However, it is not founded on any proven study but is tabled by the resin injection machine manufacturers lobby. Supposedly they are obviously concerned that their sales may be impacted by the method. Fortunately many moulders using reusable vacuum membranes in the last 8 years have no issues with air entrapment and prove such concerns are invalid.

The reason such radicle resin dispense methods where not appropriate when using traditional disposable bagging is because they are laid over the fibre pack with many pleats, folds and wrinkles to ensure their flat shape is tailored to fit the three dimensional contours of the moulded shape. Pouring resin en bloc under such would simply un-pleat the folds and allow the resin to flow unpredictably in any direction leading to dry fibre unfilled areas. Reusable membranes, on the other hand are moulded accurately to all the three dimensional shape of the mould and have no pleats or folds thus allowing the resin flow to progress in an orderly and predictable manner.

A more recent development and now established as a welcome advance in optimized resin delivery is the "morph" resin runner. So called as the smooth moulded membrane surface morphs into predetermined flow channels directing resin rapidly from a given inlet zone to the mould cavity far reaches ensuring optimized fill speeds. These temporary "morphing "resin channels will, on resin fill, morph back to a flat surface once more eliminating any fixed resin runner cure exotherm or the need of single use peel ply (Figure 3).

The two times innovation winner for the German ICE train flooring product from November 2018 JEC, Korean show and AVK award Composites Europe employed reusable vacuum membranes. These had multiple arrays of resin morphing runners built into several production membranes made by SMT, Forst, Germany (Figure 4).

Longevity of reusable membranes has recently become a hot topic with established suppliers claiming up to 350 cycles.

Platinum addition cure silicone material, used for the manufacture of reusable vacuum membranes (bags) for composites, vary enormously in quality. Generally, they are all able to achieve the necessary vacuum sealing function and have good temperature resistance. Tear resistance also varies but remarkably this has little impact upon their daily use. The main issue is their self-releasing reusable longevity performance. In other words, how long they last.

A reusable membrane, which can be reused for say 300 moulding cycles is impressive only until one learns that there are high-quality silicones which achieve 1000 cycles and more (Figure 5).

A silicone material, which achieves four times the life without any need for maintenance and recoating is seriously impressive. One would be forgiven in thinking such higher quality silicones like ACC Silicone's VBS26 would be much more expensive, however, to pay only another 20% more for potentially 400% greater longevity is extremely attractive.

Reusable membranes, often referred to as reusable vacuum bags, have now been marketed for over 10 years and in that time case histories of longevity have come to light and have been repeatedly proven. Clients are reporting excellent longevity performance with some silicone grades whilst achieving far less with others. The only difference between them is the original silicone-manufacturing source.

It is now apparent that the choice of silicone grade is a very important commercial decision and it would be false economy, as unfortunately is so often the case, to simply go for the cheapest with no regard to longevity (Figures 6 and 7).

FIGURE 3

Morphing resin runners rapidly distribute infusion resin but leave no mark on the cured part and eliminate the need for single use peel ply.

FIGURE 4

Composite award winning new low weight ICE TRAIN flooring made with reusable membranes.

FIGURE 5

Illustration of ACC Silicone membrane condition after 1200 plus uses with polyester resin moulding.

FIGURE 6

A different European silicone supplied *illustration of a riding helmet membrane after only 160 cycles using polyester resin. Note the surface peeling where the part has stuck and rendered the membrane unserviceable after such a short production life.*

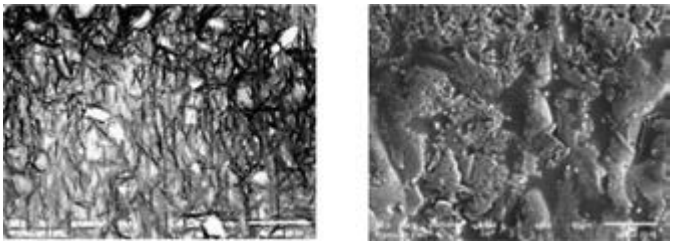

FIGURE 7

We illustrate a typical electron microscopic image of a worn-out silicone surface through styrene attack.

Although the focus here has been upon reusable membranes being used for liquid resin moulding processes, they are equally beneficial with the prepreg moulding process whether used in or outside the autoclave. Unlike consumable bags they can feature built in intensifiers, an attractive characteristic often used in prepreg but are traditionally separately positioned rather than built in.

FIGURE 8

Alan Harper.

Although reusable membrane technology could be said to be in its relative infancy the march toward much greater use within composite manufacture has a strong growth future if based upon nothing more than their production cost saving features alone (Figure 8).

ELSEVIER

FEATURE

The Novus Bike

Django Mathijsen

State of the art composites technology and electric propulsion are enabling designers to rethink the fundamental concept of motorcycles.

With 38.5 kg, it weighs only about as much as a power assisted bicycle. But with its 14 kW (peak) electric motor it has power comparable to a 125 cubic centimeter motorcycle, which would tip the scales at well over 100 kg. The Novus Bike, developed by German designers René Renger and Marcus Weidig, and unveiled at the Consumer Electronics Show 2019 in Las Vegas, is a new animal in the realm of two-wheeled private transport. Having this much power in a machine this light was achieved with an original concept that makes the most out of two cutting edge technologies: electric propulsion and fiber reinforced polymers.

Industrial designers René Renger and Marcus Weidig both grew up with a passion for motorcycles, discovering the world on two wheels as kids. So it should come as no surprise that when they decided to start their own design-studio Novus, based in Brunswick, Germany, their first prototype would be a motorcycle (http://novusbike.com [See Figure 1]). They set out to reimagine the whole concept of motorcycles, exploring all that modern technology has to offer. In doing so they found a niche that is unlike anything on the road today.

1. Complete freedom of expression

Weidig and Renger met while studying Industrial Design, which Weidig describes as "a lot of art, but also engineering, materials science and CAD-programming."

Renger adds: "We always tried to incorporate technical aspects and functionality. It wasn't just about styling, but about conceiving concepts that make a lasting statement. We have tried to realize that in this project as well."

After gaining experience in design departments in the automotive industry, they wanted to have complete freedom of expression. Because working for others, they were not always able to implement the out of the box thinking they were striving for.

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"In order to make this design, we had to free ourselves from all conventions," Weidig says (See Figure 2). "If you start with a classic motorcycle in mind, you end up with a classic looking motorcycle. It was not easy to let go of everything we knew about motorcycles and start from scratch with just this new propulsion method and finding a design that does it justice. Electric scooters and motorcycles already existed, but they were conventional machines with the motor replaced with a battery block. We said: surely that cannot be all there is?"

2. Innovative carbon fiber monocoque frame

The university taught Weidig and Renger to question things instead of accepting the status quo, but for them it was not enough to be different solely for styling purposes. "In order to justify it, it has to provide added value," Weidig says. "I think we have achieved that. Because a dry weight of less than 40 kg was only possible through this design: the carbon fiber reinforced epoxy monocoque shaped like a bicycle frame. It is a combination from many worlds. We have tried to select the best or fittest from all these worlds." (See Fig. 3).

Where Weidig was always the guy with the fastest bike, Renger says he was more into personalizing his machine: "In Germany we are allowed to ride motorcycles of up to 125 cubic centimeters when we are sixteen. When I was that young, it was all about freedom and individualization for me: expressing your own personality. I took my bike completely apart and reassembled it so it looked different from anyone else's bike. We have incorporated that feeling into our project as well: a bike that expresses the personality of the rider." It is easy to see how Marcus and René combined their passions in the Novus Bike.

3. A battery instead of a tank

Where in a conventional motorbike, the tank is probably the dominant design element, in the Novus Bike it is the lithium

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FIGURE 1

Sleek, stylish, clean, fast, futuristic, fun, sporty, purposeful and cool: carbon fiber reinforced epoxy plays a large part in giving the innovative Novus Bike its looks and functionality (Photo courtesy of Novus).

FIGURE 2

Harley Davidson's electric bike, the LiveWire, was unveiled in November 2018 at the EICMA show in Milan. With even Harley Davidson getting into the game, electric motorcycles are surely going to take up a large share of the market. But although the LiveWire is all-electric, it still has most of the classic styling cues and technologies of petrol driven motorcycles (Photo: MaggioPH/Shutterstock.com).

ion battery, which gives the machine a 96 km range and which can be charged to 80% in one hour. "We did not want to replace the tank with a battery in the classical layout," Weidig says. Being the heaviest, biggest and most prominent part of the machine, the battery is placed as low as possible in order to achieve a low center of gravity. And it was incorporated into the frame structure instead of just mounted to it (See Figure 4).

"I do not think the dominant element is the area where the battery is," Renger notes. "The dominant element is the area where there is nothing at all. Design is not just where something is placed but also where it is deliberately not placed, and the way in which you surround this area. We wanted to reduce everything as much as possible: with every decision we looked for the simplest solution." (See Figure 5).

FIGURE 3

The space where the cylinder block would be in regular motorcycles catches the eye in the Novus Bike because it is just empty and open like in a bicycle. It is as if the machine is boasting: "Nope, no internal combustion in here" (Photo courtesy Novus).

FIGURE 4

In conventional motorbikes, the energy storage (in the form of a gas tank) is on the top frame rail. In the Novus Bike it is in the form of a battery, integrated in the bottom of the monocoque frame (Photo courtesy Novus).

FIGURE 5

Why incorporate a display when virtually everyone these days carries around a smartphone, which can fulfill all of its tasks? It also acts as a digital key and controls for the bike (Photo courtesy Novus).

4. In-wheel motor

Getting down to bare essentials meant doing away with the cumbersome and heavy chain drive, gearbox and clutch of normal motorcycles altogether. The electric motor is simply fitted inside the rear wheel (See Figure 6).

FIGURE 6

The in-wheel electric motor can be seen behind the brake disc (Photo courtesy Novus).

This is feasible because electric motors have a wider usable rev range than combustion engines. An electric motor can deliver torque from standstill, rendering a conventional clutch obsolete. And because an electric motor tends to have ample torque already at low revs, it does not need as many gears as an internal combustion engine. In theory, you can even do away with the gearbox altogether.

In practice however, that is not so easy. You need to get the design and dimensioning of the whole machine and its parts absolutely right. Get it wrong and you can end up with a machine that is underpowered off the line or limited in top speed.

5. Extreme diet

"We dimensioned everything in order to optimally use its torque and dynamics in city traffic conditions," says Weidig. "It was not dimensioned for motorway driving."

In order to get away with an in-wheel motor, lightness is key. Composites were essential in achieving that, but also a construction that makes full use of their potential. "It is not a metal frame clad with carbon fiber body parts as is so often the case in motorcycles," Weidig says. "What you see is also the load-bearing structure. It is that integration that enables the low weight." (See Figure 9). The carbon fiber reinforced epoxy monocoque was made of prepregs and baked in the autoclave. The prototype was laid up by hand.

FIGURE 7

The rear swing arm is made of carbon fiber composite as well. The shock absorber is partially hidden in the frame (Photo courtesy Novus).

FIGURE 8

Even the front fork is made from carbon fiber composite on the Novus Bike (Photo courtesy Novus).

The motor itself has to be light as well so as not to upset the unsprung weight of the rear wheel assembly (and thus the bike's handling). A 14 kW (peak) brushless motor was chosen as the optimal compromise. It delivers a hefty 200 Nm of maximum torque, so the bike can propel a rider of average weight off the line at a satisfying rate of about half a g. The top speed is 96.5 km/h, which should be more than enough as well since the bike is not intended for motorway driving.

6. Carbon fiber composites all over

To compensate for the motor adding to the unsprung weight of the rear wheel assembly, the swing arms are made from a lightweight carbon fiber reinforced epoxy structure as well. A fully adjustable, progressive air damper sits neatly in an alcove in the frame (see Figure 7).

The front suspension was designed to match the frame design's low weight and look (see Figure 8). It is a single strut (also with an adjustable damper) acting on a front fork made of carbon fiber reinforced epoxy. The weight-saving single strut design, which should be enough to cater for all inner-city traffic conditions, was possible because of the whole machine's low weight. Adding more suspension travel, for example for off-road use, would have required a more conventional design with double front struts, adding width and weight to the sleek monocoque frame and thus the entire vehicle (see Figure 9).

The weight-saving philosophy was consistently carried out right down to the carbon fiber composite levers controlling monoblock calipers with 230 mm brake discs.

FIGURE 9

The single strut at the front should be man enough to handle all that inner-city traffic can throw at it. The LED-headlight is integrated in the handlebar assembly, making it nearly invisible when it is not lit (Photo courtesy Novus).

FIGURE 10

The carbon fiber composites give the Novus Bike its performance. They are also extremely beautiful when the sunlight catches its texture just right (Photo courtesy Novus).

7. Simultaneous engineering and design

Weidig and Renger do not think their design can be categorized as "form follows function", because in their design, function does not completely define and dominate form. "I would say that function, engineering and form have to go hand in hand," Weidig says. In some respects it is the original design in the first place that makes certain aspects of function and construction possible (see Figure 10).

"That was the only way in which to realize the low weight," Weidig explains. "Maximum function integration in order to have the least amount of parts and bolts, and having it all look as if it was cast in one piece. That requires simultaneous engineering and design. So, no bouncing back and forth between engineer and designer. While designing you always have to have in the back of your mind how it is all going to be made."

8. Freer than a classical motorcycle

If you have grown up with a love for motorcycles and cars, you tend to love the sound of an internal combustion engine. "Riding electric is certainly a different experience," Marcus says. "I find it feels even more free than on a classical motorcycle: it is quieter. But you definitely still hear a sound of strength exuding from the motor. And you especially feel the incredible torque from a standstill. You do not have to manipulate a clutch and gearshift lever, making the ride much more carefree. I love racing bikes and their sound. But for the environment for which we designed the Novus, starting at a café for example, it is strenuous to have all those loud vehicles going by. It feels like a blessing rolling along noiseless."

Maybe generations to come are going to acquire a taste for the soft whine of powerful electric motors and speed control electronics. As for the silent running decreasing road safety because it is impossible in traffic to hear electric vehicles coming, Marcus feels that this problem is going to decrease over time as overall road noise levels are going to decrease when more electric vehicles are on the road.

The low weight and low center of gravity make the motorcycle extremely agile in traffic. "Its maneuverability is comparable to a power assisted bicycle," Weidig says. "The rider's weight and center of gravity are more pivotal than on a conventional motorcycle. So it requires less effort from the rider." Combined with 14 kW of peak power, it makes for a unique driving experience. "It looks light, and riding it is also light," Weidig says. "The experience matches the optics." (see Figure 11).

9. New niche

Why did they choose this market segment of a superfast city runabout: a new niche, more up-market and faster than power-assisted bicycles and electric scooters, more agile and maneuverable than current motorcycles, but with a top speed too low for motorway cruising?

"We did not want to build a racing machine," Marcus says. "But you cannot be underpowered either: you always have to have enough power to feel sovereign in traffic, as well as towards your vehicle. We thought electric drive made the most sense in an urban environment with lots of stop and go traffic, especially with a very light vehicle. That makes it suitable for daily use. It is possible to make an electric motorcycle with 100 kW. But that would require a very big, heavy battery and it would be just like everything that is already out there."

We wanted it to be like nothing else on the road," Renger adds. "There are big bikes, which are comfortable and fast, and

FIGURE 11

A machine this light, powerful and agile gives the rider even more a feeling of freedom than regular motorcycles. Just like the headlight, the taillight is LED and integrated, so it is hardly visible when it is not lit (Photo courtesy Novus).

there are e-bikes, which are good for short distances. But on longer stretches you will arrive all sweaty. And they are not really cool. We wanted to make a two-wheeler that would be light and electric, that you can take into an elevator if need be, and that has a cool, positive image that sets it apart from unwieldy motorcycles and less agile bicycles. That space in-between had to be catered for. This combination of extremely low weight and high power was not on the market yet. Currently the economic perception in the western world for small, lightweight two-wheelers is: a necessary compromise for people who maybe cannot afford a car or a proper motorcycle. We wanted to shatter that perception and make a product that arouses desire. Something people want to have and can be proud to have."

10. Future

The machine also has a pretty proud price. The production model is expected to go for $39,500 plus VAT. "Tooling and handcrafting are very expensive on the Novus Bike," Weidig explains. "And we want to achieve a high level of quality."

With a pioneering concept, unique looks and a production run limited to 1000 units, buyers should get a timeless machine for their money. With the Novus Bike being the first of its breed, it will be interesting to see if other manufacturers are going to jump into this niche as well.

And will the concept of the in-wheel motor, the carbon fiber monocoque and the battery in the bottom of the frame become the standard layout for future electric motorcycles? "That is difficult to say," Marcus says. "That concept was tailored to this horsepower class. We did not consider big bikes that can do 250 km/h."

11. Finding a new DNA

When motorcars started replacing horse-drawn vehicles in the late nineteenth century, for a long time they were engineered and designed like horseless carriages (See Fig. 12). It took a while for the automobile to find its own, unique engineering and esthetic DNA, exuding confidence about its innovative technology instead of trying to downplay that it does not have the traditional means of propulsion the consumer of the time loved and trusted because he had grown up with it. With its largely exposed propulsion technology, it seems inevitable that the motorcycle is now on the verge of a comparable revolution, having to completely reinvent its engineering and esthetic DNA.

Most electric motorcycles currently on the market still look like conventional bikes trying to hide their non-petrol-burning bits as if they are ashamed for them. That is why projects like the Novus Bike are a big step forward in the search for an electric motorcycle DNA, blending shape and technology in a confident way, fully embracing and even flaunting its propulsion and materials technology.

Chances are of course that future electric motorcycles will differ as much from the Novus Bike as modern cars differ from a Rolls Royce Silver Ghost or Ford's model T. More powerful motors and batteries may require different layouts and packaging. And maybe hydrogen is going to replace batteries, leading for example to a fiber reinforced polymer monocoque frame to double as the hydrogen tank.

But the Novus Bike shows what can already be achieved with current state of the art technology, providing you start with a blank slate. It – and the new class of vehicle it represents – would not have been possible without electric propulsion and advanced reinforced plastics engineering.

FIGURE 12

Initially, motorcars looked like "horseless carriages", as can be seen in the Oldsmobile from 1901 on the left. In the 1911 Brush model E-26 roadster on the right, we can already see the automobile shedding its horseless image and starting to find its own unique engineering and esthetic DNA (Photo EhayDy/Shutterstock.com).

As carbon fiber reinforced polymers become more mainstream and as in-wheel motors and batteries become lighter and more powerful, this will open up a whole range of possibilities, maybe even as exotic as low-slung recumbents (as seen in the 1988 cult anime science fiction movie "Akira") with motors in front and rear wheels.

Maybe the Novus Bike is laying the foundation for the motorcycle's future DNA, greatly expanding the market for composites in motorcycles. Surely, its design philosophy and attitude should be the way forward for the motorcycle world: exciting times are ahead for two-wheeler enthusiasts.

12. Changing perceptions

Weidig and Renger are not willing to divulge yet what their next project is going to be. "This was a product of passion for us," Weidig says. "But we do not want to limit ourselves to motorcycles." Renger adds that they are interested in a lot of other themes as well: "Novus as a brand represents generating and implementing ideas that stand out from what is already out there: waking people up and breaking with convention."

They are looking into maybe using natural fibers and bio resins. And they are available for innovative projects, providing they match their philosophy. "The reason why we do it, is not just to make another luxury product," Renger says, "but to change perceptions, and maybe in the end even influence societal conventions."

ELSEVIER

FEATURE

Picnic benches and the circular economy

Jagan Mohan Raj

Plaswood Group, UK

With the growing need to increase plastic recycling rates, Jagan Mohan Raj – Innovation Director, RPC bpi recycled products outlines a different approach to the use of recycled polymers.

The broadcast of the Blue Planet II programme in 2017 was something of a game changer in the public's perception of plastic. From being viewed as a useful, if slightly disinteresting material, plastic almost overnight became universally demonised. Leaving aside the many inaccuracies and misconceptions that continue to surround the material as a result, one challenge that has undoubtedly arisen is the need to significantly increase recycling rates, setting a challenge for industry to effectively deal with the wide range of plastic polymer materials being collected (Fig. 1).

Often recycling is framed in terms of reusing materials to make the same products they originally were, such as bottles or other packaging. However, an additional focus is now needed to create long lasting, high-material-demand applications which can overcome the challenges within our recycling infrastructure.

How did we get here?

The breath-taking ocean vistas of Blue Planet II launched the role of plastic into the public discourse like never before, focusing on the harm done by waste plastic once it enters the environment. There is therefore an urgent need to ensure that such waste is prevented and captured effectively, and that the material can be properly reused through effective recycling.

Legislation in certain countries is also driving this. The German Packaging Act passed by the Bundestag in early 2019, for example, requires "mandatory participation" from companies in the collection and recycling of the packaging they produce. Similarly, in the UK, the Department for Environment, Food and Rural Affairs (DEFRA) is currently conducting consultations on reforming the existing packaging producer responsibility system.

Recycle more to save the planet!

At the same time, discussions on recycling have widened to focus more on the need for a circular economy, where the lifecycle of a material is extended for as long as possible, with recovery, recycling and regeneration at the end of each service cycle.

Low worldwide recycling figures are often touted as proof that the current recycling system is a failure, with the National Geographic quoting recycling rates as low as 9%. Whilst these figures can be misleading, often including countries with nothing like the necessary infrastructure to handle plastic waste (the UK's recycling rate in comparison is 32% according to the British Plastics Federation), it is clear that a great deal more can be done to increase the rates of recycling.

Problems with recycled plastics

One of the issues with recycled plastics, in particular PET (polyethylene terephthalate), is the loss of strength in the material as a result of the recycling process, where the heat and mechanical stresses break down polymer chains in the material, inherently weakening the final product. This means that typically, recycled PET cannot be used on its own to produce new bottles or packaging but requires blending with virgin material to achieve the same performance.

Whilst this is still preventing waste PET entering landfill or incinerators, it does not meet the full criteria of a 'closed loop' or circular system which manufacturers are being encouraged to move towards.

Progress is being made on this through chemical recycling processes which do not affect material strength but this method is yet to reach the mainstream.

Black plastics are another sizeable element of the waste stream that can be demanding to deal with, as the sorting equipment at most recycling facilities is unable to detect the material.

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FIGURE 1

A Plaswood table.

Manufacturers are now beginning to rise to this challenge with black plastic packaging that is compatible with sorting equipment. However, as with chemical PET recycling, this has not yet been fully commercialised and in any case only represents black plastic from consumer packaging.

One of the largest sources of black plastic is from 'plasticulture' or agricultural use of plastic. Hay bales wrapped in polyethylene film are a common sight on any drive through the countryside. This is to produce silage for cattle by creating an oxygen barrier around the bale. Fields of crops covered by polymer sheeting is another common sight. Known as mulching, the sheeting suppresses weed growth and improves soil water retention by preventing evaporation can account for 25–50% of water used by irrigation.[1]

As an aside, this particular example highlights the complex and often contradictory sustainability considerations surrounding plastics. Plastic mulching helps drastically reduce a farm's water use, another vital sustainability benefit. However, this water saving solution is only delivered through the use of plastic, something held in differing degrees of unacceptability in the eyes of anti-plastic campaigners. This is a common theme running throughout the plastics debate.

A less discussed consideration is that recycling plastic can often be a delay on final disposal rather than avoiding it completely, particularly for packaging, where eventually no matter how many times a bottle is recycled it will eventually end up in landfill or incineration.[2]

Two challenges in using recycled polymers for products have been identified here; how to deal with the loss in performance of the material from the recycling process and how to incorporate difficult-to-recycle material.

Whilst using as much recycled polymer content as possible in packaging and other fast-moving consumer goods is absolutely part of the solution, the creation of solutions that are truly circular require new processes that can overcome these challenges to become widespread and economically feasible. More focus is also needed on 'second life' products and the types of products made out of recycled plastic.

Products for the circular economy

It has been estimated that since the 1950s over 8.3 billion metric tonnes of virgin plastic has been produced. Of this amount roughly 30% is currently in use, usually in building applications such as window frames, and 9% has been recycled.[3]

This demonstrates that plastics comprise a huge amount of raw material worldwide, an amount that dwarfs demand from recycled consumer products and packaging despite modern innovations driving improved recycling rates. So, what can be done about this? One approach is to consider all the collected plastics as 'raw material' with potential as a valuable resource for long-lasting, second life construction applications.

[1] DediMa[a] LeiChen [b]HongchaoQu [a]YilinWang [a]TomMisselbrook [c]RuiJiang, 2018, Impacts of plastic film mulching on crop yields, soil water, nitrate, and organic carbon in Northwestern China: A meta-analysis, Agricultural Water Management, Volume 202, 166–173.

[2] Geyer, R., Kuczenski, B., Zink, T. and Henderson, A., 2016, Common Misconceptions about Recycling. Journal of Industrial Ecology, 20: 1010–1017. doi:https://doi.org/10.1111/jiec.12355.

[3] Roland Geyer, Jenna R. Jambeck, Kara Lavender Law. [Production, use, and fate of all plastics ever made] Science Advances 19 Jul 2017: Vol. 3, no. 7.

Plaswood, for example, is a plastic 'lumber' produced using a blend of several post-consumer polymers. This material is used to create a variety of outdoor furniture such as benches and picnic tables and is also increasingly being used in the structural and architectural sectors for products including decking, fencing and bollards.

Using this recycled plastic lumber in place of traditional materials such as wood, steel or concrete isn't simply a greenwashing gimmick. Plaswood has several benefits which make it a serious contender as a construction material: it is impervious to water and thus is weather-proof without requiring maintenance. This particular benefit is incredibly useful in wetland and waterway applications where Plaswood boardwalks, cycleways and flood barriers can be installed without the ongoing need for treatment. This gives them an extremely long lifespan, reducing the long-term cost compared to traditional timber which would need to be maintained and replaced every four to five years on average.

Other structural uses for the plastic timber are fencing and gates. The same benefits apply; a fence made from Plaswood will not need varnishing, will be more robust and last for many more years. It also has excellent UV stability, protecting against another typical source of damage for outdoor furniture.

This isn't to suggest that in a few years we will start to see entire buildings constructed from recycled plastics, but it does demonstrate how second life materials such as Plaswood are a legitimate construction material with long-term cost and sustainability benefits compared to the traditional alternatives.

Overcoming limitations

The method of production for Plaswood also solves some of the challenges faced by recycling. A common problem is the sorting of different polymer types. Bottle recyclers, for example, only want PET and must ensure that their waste stream contains just that polymer. The level of difficulty of this requirement depends on each application, but the issue remains.

Plaswood is manufactured from a polymer blend input that utilises a mixture of different post-consumer polymer types that result in a product with controlled and consistent technical properties. A mixed polymer blend makes typical extrusion methods very difficult as a stable extrudate is required, something a blend of different materials cannot provide.

This is overcome by using an intrusion moulding technique in which the plastic melt is allowed to form within the mould. This isn't a pressure dependant method and produces strong, rigid profiles which are key to Plaswood's many construction applications and avoids the loss of material strength common in other processes.

Intrusion moulding also means that the production method has reasonable tolerances for impurities in the waste inputs without compromising Plaswood's performance. This is an excellent characteristic, especially when it comes to post-consumer plastics which are likely to contain small amounts of other plastic groups such as polyesters.

A New raw material

As well as the significant contribution plastic lumber can make as a construction material due to its properties and the relative flexibility of its production in comparison to traditional plastics recycling, there is wider point that Plaswood highlights.

Consider for a moment the total mileage of wooden fencing or what the total square mileage of decking would be in the United Kingdom. Whilst an accurate answer would be nigh impossible to find, it is safe to say that whatever the figure might be it would represent an utterly colossal amount of material, primarily wood in this example.

Plaswood has demonstrated a different avenue and a new application for waste plastics in the drive towards a circular economy, a solution that has the potential to have a truly massive demand for material which would dwarf that of the consumer product and packaging sectors. This is just one example; in recent years a number of roads have been created using recycled plastics, yet another function which traditionally uses a large amount of other raw materials such as asphalt.

Sometimes less is more. Using less material to create something compared to before is usually a good thing. But when it comes to dealing with the volume of plastic out there still to be recycled, finding more uses for it is a fundamental part of the solution. It is time to see plastics, not as waste but as a large and valuable resource of raw material that has a wide array of potential applications.

Imaginations have been limited in how to use this resource and demand has been far outstripped by supply. Plaswood is by no means the only path forward but represents a new way of thinking on how to use waste plastics. Here's to hoping this is just the beginning of this new direction.

ELSEVIER

FEATURE

When relining potable water networks becomes reality

Liz Nickels

A new relining process involving a styrene-free resin suitable for drinking water applications allowed engineers to renovate an old pipe in the middle of Amsterdam with minimal upheaval. Liz Nickels spoke to resin supplier AOC Aliancys about the process and its future use.

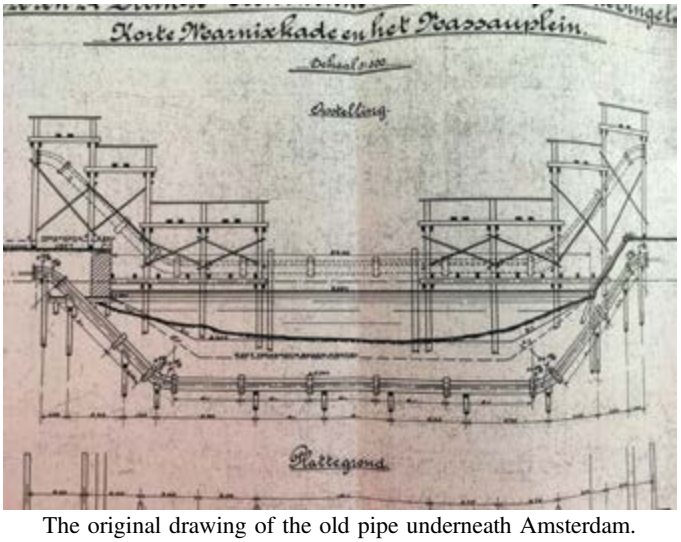
While composites have become very common in infrastructure projects, with utility companies benefiting from the material's long life and excellent corrosion resistance when compared to steel, they really come into their own when flexibility of installation is required.

The relining process itself is not new. Already back in 1971, Insituform Technologies, which specializes in pipe relining, manufactured and installed the first ever cured-in-place pipe (CIPP) liner in a 900 mm × 600 mm brick egg sewer located in Hackney, London. However, making use of composite with styrene free resin that has approval for contact with drinking water is a very recent innovation.

After the unexpected collapse of a drinking water pipeline in downtown Amsterdam, the capacity of the potable water supply network to the town center was significantly reduced. The pipeline collapsed along with part of the quay near the Nassaukade street in historic Amsterdam, a busy part of the city. The 600 mm diameter pipe was an important part of the city's drinking water network, delivering water to a large number of households in the center of town. Repairing the existing pipeline was not an option. 'The customer initially thought that a brand-new pipe would need to be installed as a permanent solution,' said Ton van Geest, R&D manager of Insituform Europe. 'However, they realized this involved doing major construction work in a very busy part of the town. Because of the complexity of the operation, it meant that both road and water traffic would likely be blocked for several months.'

'The old pipe was completely damaged – but luckily there was a second part, an old steel pipe that could be relined and act as replacement,' added Rob van de Laarschot, head of technical service at AOC Aliancys Europe. 'Up till now the lining process has mainly been used to reline pipes for sewer applications. It has developed a great deal as a technology and is frequently used all over Europe and the US and is also starting to become more used in China. Of course, the idea of making a new pipe inside an existing pipe without having to dig up the existing pipe is very attractive.'

The soil underneath the historic town of Amsterdam is relatively soft, he explained, which meant that during larger construction projects extra care had to be taken to avoid major soil displacements, which could potentially lead to cracks in historic buildings and costly reparation work as a result. In the case of pipe replacement, the impact on the environment would include noise, dust generated during installation, vehicle movement and energy consumption.



The original drawing of the old pipe underneath Amsterdam.

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Relining techniques

The nearby cast-iron pipe under the canal was, although 100 years old, unused. The aim then was to convert the 600 mm diameter, 50 m long pipe into a new drinking water pipeline by applying composite relining techniques. In this process, the soft liner is blown up and cured by hot water, resulting in a strong, durable, pipe inside a pipe. The liner is made of felt and reinforced with glass fiber, and is impregnated it with AOC Aliancys' styrene-free Beyone 700-T-01 FC resin. According to Van de Laarschot, the ingredients of this resin are on the positive list for food contact applications and the resin is manufactured in line with good manufacturing practices (GMP), therefore perfectly suitable for applications in contact with drinking water. This glass fiber reinforced resin liner system has received the KIWA-ATA approval from KIWA, a well known supplier of testing, inspection and certification services based in The Netherlands.

The location of the collapsed pipe.

Insituform and Switzerland-based AOC Aliancyshave been working together for the last five years to develop this novel relining technology.

Because of the great site preparation, an experienced crew and the benefits of the material system, engineers were able to reline the pipe in only two days, while the renovated drinking water pipeline was back in service within five working days. The companies say that this repair will extend the pipeline's life for at least 50 years.

'Our customer was very happy with the support received from Insituform and AOC Aliancys during project preparation and execution,' said van Geest. 'They were delighted that the whole renovation did not require major reconstruction work. Obviously, this was also a relief to the nearby residents. Through this technique we create a new, clean and resilient pipe inside the existing pipe. The composite pipe provides structural integrity, corrosion resistance, and can cope with water pressure fluctuations, ensuring a reliable network operation for many years to come.'

Project challenges

I spoke to Rob van de Laarschot about the challenges of the project. 'The use of relining for drinking water applications is more complex than for sewer pipes due to pressures inside the pipe. Drinking water pipes are operated under pressure, while sewers pipes in general are not. As a result, we needed to use a composite that can withstand pressure of around three to six bars. At the same time, the composite pipe should of course fulfill all local approvals for drinking water because it is in direct contact with the drinking water.

Rob explained the process in more detail. 'In this case, the reinforced liner was impregnated with the resin at Insituform premises, and then the impregnated uncured material was transported to the job site,' he explained. 'At the job site, using water pressure, engineers inverted the pre-impregnated liner into the steel host pipe, heated the water that was used for the inversion and used it to cure the resin. As the material was cured the water was heated 80 °C for two hours then cooled down slowly. The water was then removed, and we obtained a cured material inside the old steel pipe.'

The development of this liner system required the input of authorities to ensure drinking water standards were being met. 'The inside of this composite pipe can come into contact with potable water because all the materials meet the requirements of drinking water companies such as KIWA.'

Cost balance

'The biggest benefit of this entire project was that engineers could keep the old pipe in and replace it with a composite one,' Rob explained. 'Of course, composite material also has improved strength, stiffness, corrosion resistance and so on. It might have been possible to apply a thermal plastic layer, but for that layer to cope with the high pressure of drinking water pipes it would be necessary to increase the wall thickness to the extent that it might affect water flow.

Engineers were able to reline the pipe in only two days.

In terms of cost it all balances out, Rob says. 'While this process is more expensive than digging up and replacing the old pipe, the cost of closing a street for weeks can lead to untold costs and loss of earnings for inhabitants and people working in the location. If a water authority decides to keep the old pipe in place under the ground and repair it in situ, this kind of composite lining system is by far the most preferred.'Rob notes that relining drinking water pipes requires more specialist skills, compared to working with sewer pipes. 'Engineers working with this material need to

be specially selected and trained. For the Amsterdam project, because the technology is quite new, AOC Aliancys trained the crew dealing with this material and the customer to ensure that a certain quality was achieved. Measures need to be put in place to work in a hygienic way with. All the equipment needs to be hygienic and free of pollution, and engineers have to work according to a certain procedure to end up with the required quality for drinking water pressure pipes. And you can imagine that is completely different when you are working in sewer repair.'The companies are also undertaking similar projects in the Netherlands and in Cordoba, Madrid and Barcelona, Spain. 'Over the coming years we expect that take up of this technology and material will grow significantly. However, many countries have numerous water companies – for example, in The Netherlands there are 11 different water companies in the provinces responsible for drinking water – and they all need to be convinced that this technology can help them. Following this positive experience of using the novel relining system in downtown Amsterdam, we believe we have another good case where Insituform and Aliancys were able to clearly demonstrate the power of drinking water relining.'

AOC Aliancys; www.aocaliancys.com

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Events Diary

11–15 August 2019
San Diego, CA, USA
Nanoscience + Engineering 2019
Contact: International Society for Optical Engineering
Tel: +1 (360) 676-3290
Fax: +1 (360) 647-1445
E-mail: spie@spie.org
www.spie.org

20–21 August 2019
Washington DC, USA
Unmanned Systems Defense 2019
Contact: AUVSI (Association for Unmanned Vehicle Systems International)
Tel: +1 (703) 845 9671
Fax: +1 (703) 845 9679
E-mail: esinoimeri@auvsi.org
www.thedefenseshow.org

29–31 August 2019
Mumbai, India
Technotex India 2019
Contact: FICCI (Federation of Indian Chambers of Commerce & Industry)
Tel: +91 11 23738760-70
Fax: +91 11 30910411
E-mail: ficciexhibition@ficci.com
www.technotexindia.in

3–5 September 2019
Bristol, UK
Adhesions 2019
Contact: The Institute of Materials, Minerals and Mining
Tel: +44 20 7451 7300
www.iom3.org/society-adhesion-adhesives

3–5 September 2019
Birmingham, UK
Advanced Composites in Construction
Contact: NetComposites Ltd
Tel: +44 (0) 1246 266 246
E-mail: info@netcomposites.com
acic-conference.com

3–6 September 2019
Las Vegas, NV, USA
INTERDRONE 2019
Contact: BZ Media LLC
Tel: +1 (631) 421 4158
E-mail: info@bzmedia.com
www.interdrone.com

10–13 September 2019
Wichita, KS, USA
ICOLSE 2019: International Conference on Lightning and Static Electricity
Contact: Wichita State University
E-mail: icolse2019@gmail.com
www.icolse.com

10–13 September 2019
Husum, Germany
HUSUM Wind 2019
Contact: BWE
E-mail: info@husumwind.de
Tel: +49 4841 902-0
Fax: +49 4841 902-246
www.husumwind.com

10–12 September 2019
Stuttgart, Germany
Composites Europe 2019
Contact: Reed Exhibitions Deutschland GmbH
Tel: +49 211 901 91-0
Fax: +49 211 901-91-123
E-mail: info@composites-europe.de
www.composites-europe.com

11–12 September 2019
Birmingham, UK
Materials World and Recycling and Waste Management Show
Contact: PRYSM Group
Tel: +44 0117 929 6083
www.rwmexhibition.com/features/materials-world

12–15 September 2019
Tianjin, China China Helicopter Exposition 2019
Contact: abe (advanced business events)
Tel: +33 (0)1 41 86 41 60
Fax: +33 (0)1 46 04 57 61
E-mail: rportier@advbe.com
www.helicopter-china-expo.com

23–26 September 2019
Anaheim, CA, USA
CAMX 2019
Contact: ACMA
Tel: +1 703.525.0511
E-mail: info@thecamx.org
www.thecamx.org

24–25 September 2019
Raleigh, NC, USA
Contact: RISE 2019
INDA (Association of the Nonwovens Fabrics Industry)
Tel: +1 (919) 459 3700
Fax: +1 (919) 459 3701
E-mail: dlovell@inda.org
www.inda.org/events

30 September–4 October 2019
San Sebastian, Spain
Trends in Nanotechnology 2019
Contact: Phantoms Foundation
E-mail: info@phantomsnet.net
www.tntconf.org

1–3 October 2019
Tampa, FL, USA
IBEX 2019
Contact: Anne Dunbar
Show Director
Tel: +1 716 662 4708
E-mail: anne@ibexshow.com
www.ibexshow.com

1–2 October 2019
Berlin, Germany
Pigment and Color Science Forum 2019
Contact: Smithers Rapra
Tel: +44 (0) 1939 250383
Fax: +44 (0)1939 251118
E-mail: info@rapra.net
www.pigmentmarkets.com

8–9 October 2019
Krakow, Poland
Kompozyt-Expo 2019
Contact: Targi w Krakowie Ltd
Tel: +48 12 644 59 32
Fax: +48 12 644 61 41
E-mail: kompozyty@targi.krakow.pl
www.kompozyty.krakow.pl

22–24 October 2019
Moscow, Russia
Testing & Control 2019
Contact: ITE Moscow
Tel: +7 (499) 750 0828
Fax: +7 (499) 750 0830
E-mail: control@ite-expo.ru
www.testing-control.ru

30–31 October 2019
Birmingham, UK
Advanced Engineering Birmingham 2019
Contact: Easyfairs UK Ltd
Tel: +44 (0)20 8843 8800
Fax: +44 (0)20 8892 1929
E-mail: uk@easyfairs.com
www.easyfairs.com

23–25 October 2019
Lisbon, Portugal
European Graphene Forum 2019
Contact: Dubai Studio City
Tel: +33 (0)1 48 72 88 98
Fax: +33 (0)1 48 72 88 98
E-mail: info@setcor.org
www.setcor.org

12–13 November 2019
London, UK
The Commercial UAV Show 2019
Contact: Terrapinn Holdings Ltd
Tel: +44 (0)20 7608 7030
Fax: +44 (0)20 7608 7040
E-mail: enquiry.uk@terrapinn.com
www.terrapinn.com/exhibition/the-commercial-uav-show

13–14 November 2019
Nantes, France
Composite Meetings 2019
Contact: abe (advanced business events)
Tel: +33 (0)1 41 86 41 60
Fax: +33 (0)1 46 04 57 61
E-mail: info@advbe.com
france.compositesmeetings.com

13–15 November 2019
Seoul, South Korea
JEC ASIA 2019
Contact: Christian Strassburger, events director, Asia
Tel: +65 90 69 91 51
E-mail: strassburger@jeccomposites.com
www.jec-asia.events

20– 21 November 2019
Santa Clara, CA, USA
Graphene & 2D Materials USA 2019
Contact: IDTechEx Ltd
Tel: +44 (0) 1223 813703
Fax: +44 (0) 1223 812400
E-mail: events@IDTechEx.com
www.grapheneusa.tech

20–22 November 2019
Mumbai, India
World of Composites at Techtextil India
Contact: Messe Frankfurt
Tel: +91 22 61445957
Fax: +91 22 6144 5999
E-mail: info@india.messefrankfurt.com
techtextil-india.in.messefrankfurt.com

3–5 December 2019
Cologne, Germany
Fire Resistance In Plastics 2019
Contact: Applied Market Information Ltd
Tel: +44 (0) 117 924 9442
Fax: +44 (0) 117 311 1534
E-mail: info@amiplastics.com
www.amiplastics.com/events

11–13 December 2019
Shanghai, China ANEX/SINCE 2019
Contact: UBM Asia Ltd
Tel: +852 2827 6211
Fax: +852 3749 7342
E-mail: damian.goh@ubm.com
www.asianonwovens.org

11–12 December 2019
Scottsdale, AZ, USA
American Aerospace & Defense Summit 2019
Contact: Generis Group
Tel: +1 (416) 298 7005
E-mail: info@generisgp.com
www.aadsummit.com

15–17 January 2020
Tokyo, Japan Automotive Weight Reduction Expo 2020
Contact: Reed Exhibitions Japan Ltd
Tel: +81 (0)3 3349-8501
Fax: +81 (0)3 3349-8599
E-mail: car@reedexpo.co.jp
www.altexpo.jp

29–31 January 2020
Tokyo, Japan
NANO TECH 2020
Contact: JTB Communication Design
Tel: +81 03-5657-0759
Fax: +81 03-5657-0645
E-mail: nanotech@ics-inc.co.jp
www.nanotechexpo.jp

11–16 February 2020
Singapore, Singapore
Singapore Airshow 2020
Contact: Experia Events Pte Ltd
Tel: +65 6542 8660
Fax: +65 6546 6062
E-mail: sales@singaporeairshow.com.sg
www.singaporeairshow.com

31 March–3 April 2020
Geneva, Switzerland INDEX 2020
Contact: Edana
Tel: +32 (0)2 734 9310
Fax: +32 (0)2 733 3518
E-mail: info@palexpo.ch
www.index17.org

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