ECF recycled carbon fibre mats.

Powerful new partnerships

The UK's ELG Carbon Fibre is positioning itself at the centre of a new integrated supply chain for the supply of nonwovens based on recycled carbon fibre, with a number of potential new end-use markets.

It's been a hectic few months for ELG Carbon Fibre (ECF), to say the least. At the beginning of December 2018, the company announced a partnership with Boeing to recycle excess aerospace-grade composite materials, which will be used by third party companies to make products such as electronic accessories, wind blade components and automotive equipment.

This development was followed by a second announcement concerning the aim of Japan's mighty Mitsubishi Corporation to acquire a 25% stake in ECF.

For ECF managing director Frazer Barnes, these two major milestones in the company's development have unsurprisingly required endless meetings with respective management and legal teams, but at the JEC World composites show in Paris (March 12-14th) he said that all matters pertaining to the Mitsubishi deal were set to be concluded in a matter of weeks.

The result will be a first-of-its-kind integrated supply chain for carbon fibre recycled products and also a significant new market for needlepunched nonwovens as reinforcements for composites.

Boeing

The arrangement with Boeing initially covers the supply of around one million pounds of excess carbon fibre from US sites in Washington to ECF. This amount is expected to double over the next five years as excess material is collected from all Boeing's composite manufacturing sites globally.

As a result of this partnership, ECF estimates the number of its employees will nearly triple from 39 in 2016 to an expected 112 by the end of 2019, as the recycling market continues to expand.

As the largest user of aerospace-grade composites from its commercial and defence programmes, Boeing has been working for several years to create an economically-viable carbon fibre reuse industry. The company has improved its production methods to minimise waste and developed a model for collecting what scrap material is generated.

Technical barriers, however, have stood in the way of repurposing material that has already been cured or otherwise prepped for use in Boeing's manufacturing processes. These barriers have now been successfully addressed by ECF with proprietary processes.

"Recycling cured carbon fibre was not possible just a few years ago," says Tia

Benson Tolle, Boeing materials and fabrication director. “We are excited to be collaborating with ECF and leverage innovative recycling methods to work towards a vision where eventually, no composite scrap will be sent to landfills.”

“Recycling composites will eventually be as commonplace as recycling aluminium and titanium,” predicts Kevin Bartelson, Boeing 777 wing operations leader.

Pilot project

To prove that the recycling method can be applied on an industrial scale, Boeing and ECF conducted a pilot project to recycle carbon waste from Boeing’s Composite Wing Centre in Washington, where the huge wings for the 777X plane are made.

ECF put the excess materials through its furnace-based process, which vaporizes the resin holding the carbon fibre layers together and leaves behind clean material. Over the course of 18 months, the companies saved some 380,000 pounds of carbon fibre, which was cleaned and sold to companies in the electronics and ground transportation industries.

Mitsubishi

The agreement with Mitsubishi Corporation will further see ECF products promoted through some well-established global sales and marketing channels. Via Mitsubishi’s network and broad interface with different industries, the two companies aim to enhance the business development and reliable supply of reprocessed carbon fibre by ECF.

While Japan is the global leader in carbon fibre technology, producing almost 70% of the world’s supply, it’s fair to say its recycling technologies have not developed at the same pace, and this new partnership addresses an important barrier to the mass adoption in industries where sustainability and environmental impact are important.

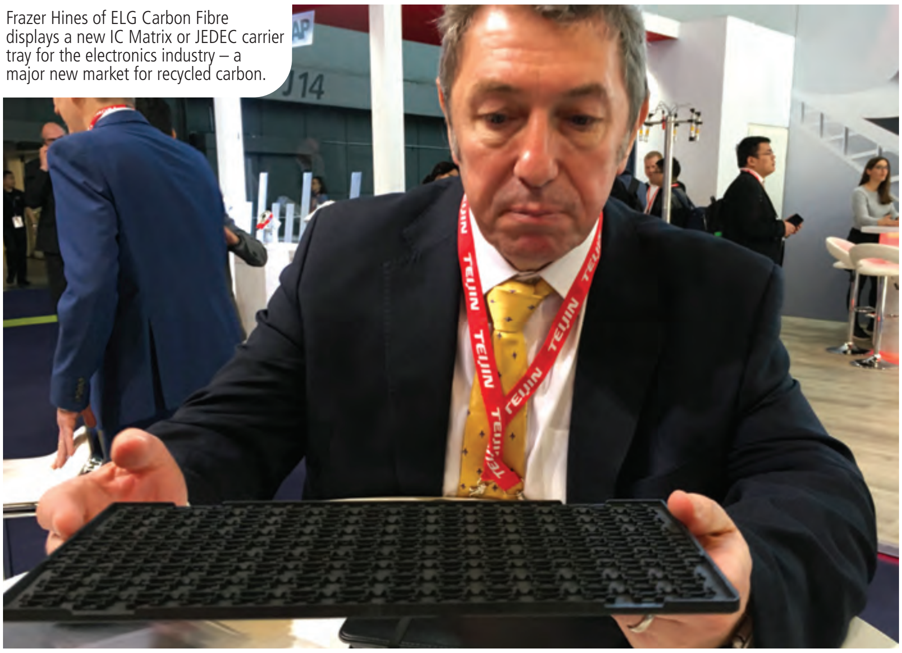
As is the case throughout the global automotive industry, for example, Japanese OEMs are seeking lightweight advanced material solutions to reduce emissions from internal combustion engines and increase cruising distance of electrified vehicles.

“This agreement will also provide resources to support our expansion, whilst strengthening ECF’s access to key transportation markets within Asia and North America,” says Frazer Barnes.

Background

ECF was formed when ELG Haniel acquired Recycled Carbon Fibre in 2011. Since then it has created the world’s first and largest carbon fibre recycling plant in Coseley, West Midlands in the UK.

Its primary focus has been to develop and industrialise the conversion technologies to manufacture recycled carbon fibre products that can be reintroduced into the supply chain.


Frazer Hines of ELG Carbon Fibre displays a new IC Matrix or JEDEC carrier tray for the electronics industry – a major new market for recycled carbon.

The high cost of carbon fibre – at still around US$10,000 per ton – makes the prospect of recycling it wherever possible very appealing, and at present, the needlepunching of industrial waste carbon fibre into new nonwoven products is the most effective route.

To add some context, over the past thirty years, the aerospace industry has developed methods for determining precise performance properties for carbon composites, established many new processing techniques and set up extended supply chains.

As a consequence, carbon composites now account for over 50% of the weight of the latest Airbus and Boeing planes. They are also now used in many other fields such as ground transportation, construction, wind energy, pipes and tanks, marine and electrical and electronics.

According to the German industry association Carbon Composites, the carbon fibres for composites market had a value of $23.1 billion in 2018, based on the supply of some 78,500 tonnes of carbon fibres to make 154,700 tonnes of carbon composites.

Carbon composite parts can be considerably stronger than those made from steel, yet the density of carbon fibre is also considerably lower than that of steel, making it ideal for applications requiring low weight, and this has ensured its rise in aerospace applications for significant fuel savings over the lifetime of a plane.

However, because carbon fibre is still very expensive, its wider use in certain fields such as mass transportation has been restricted.

Technology

Nonwoven technology suppliers including Autefa, Dilo, Tatham and Ying Yang manufacture dedicated needlepunching lines and other equipment for the recycling of carbon composite waste.

Around 20,000 tonnes of waste is already generated each year during the production of carbon fibre composites, according to Autefa. In many hand lay-up processes that use carbon fibre › woven material, for example, waste material can easily account for 50% or more of the total weight of carbon used. This waste is generated as the fabric is initially being cut, before impregnation with the matrix material. Additional waste is generated after the composite has been cured and during the post processing steps where the shape of the final part is further refined.

Autefa offers both its Airlay K 12 and specially-developed Carbon Card as web forming machines and its Stylus needleloom and HiPerTherm oven for the bonding of recycled carbon webs, and, as reported in this month's news on page six, is just opening a €3.5 million lab at its technical centre in Linz, Austria, dedicated to the processing of carbon.

Dilo meanwhile showed a complete line for the development of products from recycled carbon fibres at ITMA 2015 in Milan. It was subsequently installed at the Institut für Textiltechnik (ITA) in Augsburg, Germany, and consists of bale opening, feeding, carding, crosslapping, needling and winding. This line is characterised by a compact design, fast adaption to changing production conditions and economic operation and is allowing ITA to focus on the development of new hybrid materials from differing types of carbon waste.

Second life

According to Frazer Barnes at ECF, there are three stages to turning carbon composites into useful second life products:

- Recovery of the fibres from the waste.
- Conversion of the recovered fibre into a useable intermediate.
- Manufacture of the second life component.

There are five main types of product that ECF now produces from the reclaimed fibres:

- Milled fibres, which are used to make thermoplastic and thermoset compounds and for additive manufacturing processes. The main benefits conferred by milled fibres are increased stiffness, higher electrical and thermal conductivity and reduced coefficient of thermal expansion.
- Chopped fibres, which are used for reinforcement of thermoplastic and thermoset compounds.
- Carbon fibre masterbatch products, which will be commercialized in 2017, where ELG takes chopped fibres and converts these to masterbatch products for use in the compounding industry.
- Hybrid nonwoven mats, combining carbon fibres with thermoplastic fibres such as PP and PA.
- Carbon fibre nonwoven mats for composites manufacturing.

Challenges

According to ECF, the main challenges in recycling carbon fibre composites have included dealing with the complex nature of the waste streams. Even relatively clean waste streams from composites manufacturing still contain resins of varying chemical composition and unwanted materials such as paper or plastic backing films, and the recycling process has had to be optimised to ensure the complete removal of these unwanted materials without damaging the fibres.

The second challenge is classification of the fibres. The composites industry has grown up with a wide variety of carbon fibre grades available from different manufacturers. Although the recycling process has only a small effect on the properties of the fibre, it is not desirable to retain the original fibre designation after fibre recovery. ECF has addressed this by introducing a generic classification system based on the Young's modulus and tensile strength range of the recovered fibres.

ECF recycled carbon nonwovens roll goods.

Processes

There are several processes which are either commercially exploited or under development whereby discontinuous fibres are converted into intermediate products. Several companies produce nonwovens using short carbon fibres. In many cases these are still virgin fibres and come from offcuts, weaving selvedge etc. The nonwoven textiles can be made by the air laying, carding, or wet-laid processes.

The other approach being employed is to chop the fibres to a fairly short length (a few millimetres) and then mix these with either a thermosetting resin to make a sheet or bulk moulding compound or with a thermoplastic melt to produce a compound for injection moulding. Care has to be taken during mixing to avoid fibre breakage.

Recovery of the fibres from parts already impregnated with resin is more complex, but can be done by pyrolysis or solvolysis.

Solvolysis and Pyrolysis

In solvolysis the resin matrix is decomposed or dissolved by a solvent. As composite resins are generally engineered to be durable in typical service conditions, they tend to have excellent resistance to chemicals. Dissolving the resin therefore requires aggressive chemicals and/or elevated temperatures and pressures. For example, it is known that carbon fibres can be liberated from an epoxy laminate by boiling it in concentrated nitric acid for several hours (ISO 14127). It has also been proven that a supercritical acetone/water mix (320 °C, 170 bar) also dissolves the resin. Neither method has been scaled up to tonnage quantities and there are still significant challenges to be addressed before this technology becomes commercially viable.

Pyrolysis is the decomposition of the resin by heat. It can be done in a number of ways. It can be done in a batch process using an inert atmosphere or vacuum. This decomposes the resin to a mixture of chemicals which tend to volatilise from the resin and then condense in the outlet as 'pyrolysis oil' which can be burnt as a fuel or distilled to recover chemicals. However, the process also generates a char which is a hard glassy (non-crystalline) carbon and this can be well adhered to the fibres and bond fibres together. Char can only be removed by oxidation.

Continuous pyrolysis

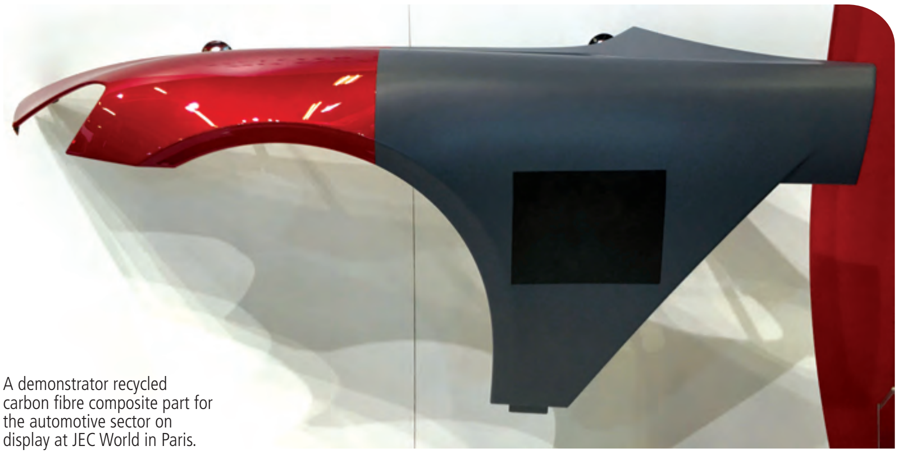
Carbon fibres are relatively oxidation resistant up to about 500°C, therefore it is possible to burn off the resin and with careful control of the conditions inside the furnace still avoid a significant loss in strength. This is the method employed at ECF in a patented furnace process called 'continuous pyrolysis'. Combustion of the resin depletes the oxygen levels in the furnace so the oxidation of the fibre is minimised. The presence of oxygen minimises char formation because entropy considerations do not favour char formation over combustion and any char which is formed oxidises faster than the fibres.

Regardless of how the fibres are won from the waste, they are liberated as discontinuous, poorly aligned fibres. Subsequent processing is necessary to take this low bulk density material to convert it to products which the industry wants to buy.

Industrial scale

ECF has now established the recycling of carbon fibre waste at an industrial scale of above 1,000 tonnes per year, based on the thermal removal of resins in a controlled environment at temperatures in the range of 400-650°C.

Under its Carbiso and Carbiso M brands, it is manufacturing nonwoven mats made from the 100% recycled carbon fibre, and those in blends with thermoplastic fibres. These products have a relatively high loft, good drape and a consistent fibre areal weight.



A demonstrator recycled carbon fibre composite part for the automotive sector on display at JEC World in Paris.

Prodrive Composites of Banbury, UK, has developed a process for manufacturing recyclable composite components called P2T (Primary to Tertiary) using ECF's Carbiso M nonwoven mat.

As the nonwoven reinforcements for new composite products, they can be used in processes including prepreg compression moulding, liquid compression moulding and vacuum infusion and their very regular surface enables high quality finishes to be achieved.

In hybrid products, recycled carbon fibres can be further combined with virgin carbon fibres to produce lightweight structures that otherwise would not be economic. Typically, such structures comprise 10-20% virgin carbon fibre.

New markets

One high volume market in which ECF now anticipates success is in the supply of IC Matrix or JEDEC carrier trays employed in the electronics industry. These are specified to meet established standards for the safe handling, transport and storage of integrated circuits, modules and other components.

The single order quantities required by this industry of anything up to 100 tonnes have been impossible to meet in the past, yet composites based on recycled carbon fibre, or hybrids, are perfectly able to meet the specifications required.

Further opportunities exist in the wind energy sector, where the strength of carbon fibres is now becoming necessary to supplement glass fibre-based blades as they become increasingly longer.

"Security of supply is extremely important when considering using these materials in long-term projects," says ECF managing director Frazer Barnes. "The agreements with Boeing and Mitsubishi give us the ability to provide that assurance, which in turn gives our customers the confidence to use recycled materials." **SNW**