Ten questions for...

Frazer Barnes

Managing Director, ELG Carbon Fibre

Sustainable Nonwovens: What is the background to ELG Carbon Fibres as it is today?
Frazer Barnes: ELG Carbon Fibre 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.

While we continue to optimise the carbon fibre recovery process, our primary focus is to develop and industrialise the conversion technologies to manufacture recycled carbon fibre products that can be reintroduced into the supply chain. During 2015, the company reclaimed more than 1,000 tonnes of carbon fibre from manufacturing waste and converted this into products that were returned to the market.

We place a strong emphasis on R&D and are currently working in partnership with the leading universities and research organisations around the world to improve understanding of recycled carbon fibres and how they can be used. ELG has been part of the Haniel Group, a German family-equity company headquartered in Duisburg-Ruhrort, since 1982.

SNW: What has your latest expansion plan involved?
FB: During 2016, we began manufacturing a range of nonwoven mats on a new production line which is specifically designed to process recycled carbon fibres. The mats are available in widths up to 2.7m at fibre areal weights from 90gsm to 600gsm. The new machine has been custom built and installed at the company's HQ in the West Midlands to our exacting specifications. Designed and manufactured in the UK, it can produce a variety of nonwoven materials including 100% recycled carbon fibre mats and thermoplastic blends such as carbon fibre mixed with PP, PA, PPS fibres.

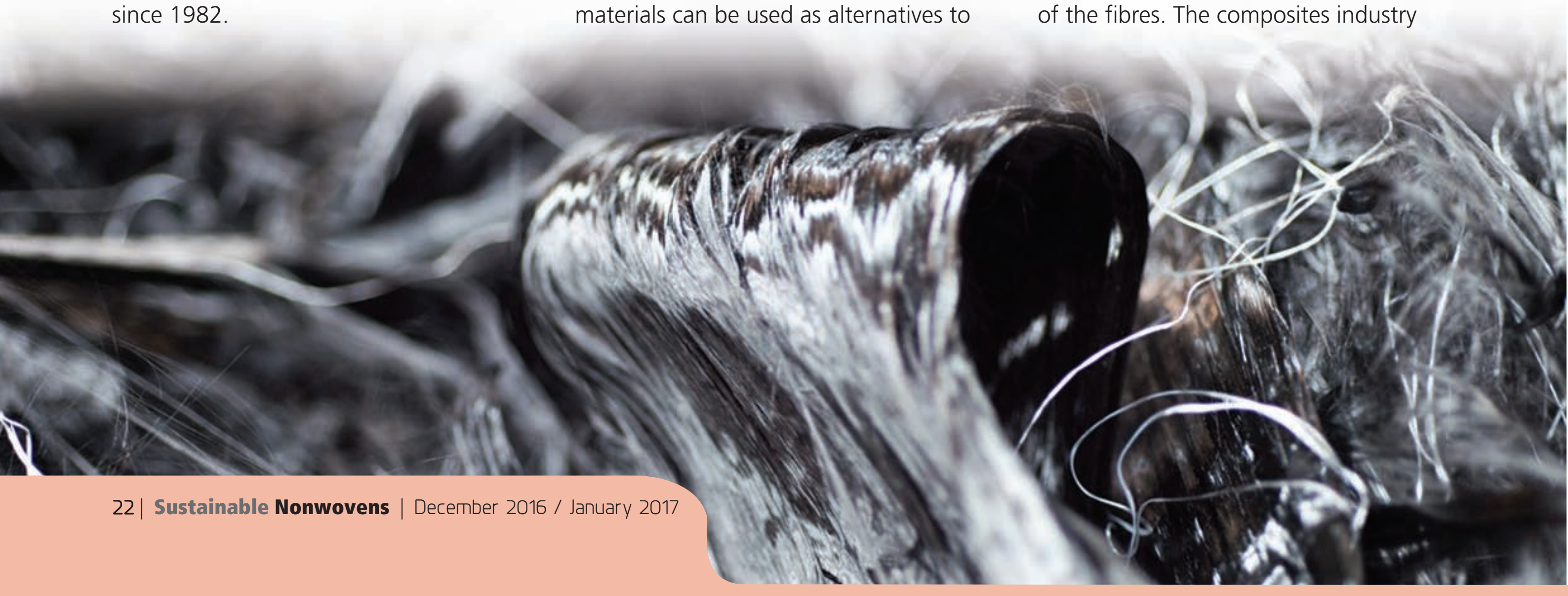
The machine is unique in being able to use reclaimed carbon fibres that have been obtained through pyrolysis of scrap prepreg materials or cured laminates, providing important feedstock flexibility compared to existing equipment available in the marketplace which can only accept dry manufacturing waste.

The nonwoven range of materials will strongly appeal to OEM's in the transportation sector seeking cost effective options for lightweighting. The materials can be used as alternatives to or in conjunction with virgin carbon fibre, and as alternatives to aluminium where greater weight saving or increased design flexibility is required.

In July 2016, we also joined IACMI – The Institute for Advanced Composites Manufacturing Innovation. The affiliation will increase our engagement with end users and a variety of development projects, allowing the company to accelerate plans for expansion into the US as part of its strategy to develop a global footprint.

SNW: What are the main difficulties in recycling carbon fibre composites?
FB: The major challenge is 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 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. ELG has addressed this by introducing a generic classification system based on the Young's modulus and tensile strength range of the recovered fibres.

The final challenge is in the development of the business. The major barrier that must be overcome is one faced by all new materials – lack of knowledge about mechanical properties and processing characteristics, and lack of large scale demonstrators that prove the economic, technical and environmental justification for using these materials. While there are a number of projects that are addressing these issues, the push from the manufacturing side of the supply chain to find a solution to its carbon fibre waste problem generally isn't matched by a pull from the design side of the supply chain, to find ways of using recycled carbon fibre products.

SNW: What routes exist for turning carbon composites into useful second life products?

FB: There are three stages to producing 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.

Each of these contains within it a number of options and processes. The third is outside the scope of this article but it is the intention of ELG to make intermediates which the composites industry can directly substitute for virgin carbon fibre products.

Recovery of the fibres can be done by pyrolysis or solvolysis. 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.

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 ELG Carbon Fibre. 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.

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 and the like. 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.

SNW: What is the method you have selected?

FB: We employ a patented furnace process to convert the reclaimed fibres called 'continuous pyrolysis'. This › involves the thermal removal of resins in a controlled environment at temperatures in the range of 400-650°C. This process, which is optimised for different types of feedstock, results in clean fibres (all residues removed) which have very similar properties to the original fibre. From a cost and fibre quality standpoint, this is most commercially viable process for carbon fibre recycling.

There are five main types of product that ELG produces from 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.

SNW: What are the key performance properties of your new Carbiso M and TM products?

FB: Carbiso M and Carbiso TM are isotropic mats that are easy to handle, drapeable and compatible with most thermoset and thermoplastic polymers and deliver excellent mechanical properties.

Carbiso M mats are produced from 100% recycled carbon fibre and can be processed by conventional composite techniques to manufacture structural and semi structural parts.

Carbiso TM products are hybrid mats produced from recycled fibres and comingled with thermoplastic matrixes for press moulding applications.

Carbiso M and TM mats are available in standard 100-600gsm weights and 2.7 metre widths. To offer customers total flexibility and an entirely tailored solution, the mats can also be manufactured to bespoke specifications.

Composites made from Carbiso M and TM mats have mechanical properties that are competitive with more conventional quasi-isotropic materials made using similar manufacturing processes.

SNW: Is this all post-industrial recycling? What about post end-use?

FB: Currently, there are large volumes of manufacturing waste that are consigned to landfill or incineration, and the priority of the composites industry is to deal with these waste streams. We estimate that less than 10% of manufacturing waste is currently recycled.

At the same as addressing the issue of manufacturing waste, we are actively developing end of use recycling concepts for automotive and aerospace parts, that address the challenges presented by the complexity of these structures. Although the amount of carbon fibre available from such sources is limited today, it is expected that within 5 to 10 years, sufficient carbon fibre will become available from such sources to make this a viable feedstock source.

SNW: What are the current and potential future applications of these materials?

FB: ELG Carbon Fibre views high volume transportation applications as the key emerging market that could best benefit from the company's products and services. If the vehicles of the future are manufactured from increased quantities of recycled carbon fibres, these lightweight structures will be more cost effective and in turn reduce CO_2 emissions, increase compliance with fuel economy regulations and also support the European Union (EU) end-of-life-vehicle (ELV) directive.

SNW: How big is the market for recycled carbon now, and how big do you believe it will become?

FB: The market is small right now because people don't yet have full confidence in the materials. However, once this hurdle is overcome then the market for recycled fibre is only limited by the supply of material. The market for virgin carbon fibre is currently US$2 billion and is growing annually at 12 per cent. Oak Ridge National Laboratory has forecasted that by 2020 there will be an excess of demand over supply to the tune of about 15 per cent of total demand. Recycled fibre can meet this deman,d because on current data about 30 per cent of all fibre produced is scrapped somewhere along the composite manufacturing supply chain. Therefore, by 2020 the market for carbon fibre will be $3.5 billion and about $500 million will be in recycled fibre based products.

SNW: What do you consider to have been the biggest developments in the composites industry so far in the 21st Century?

FB: The 787 Dreamliner represents a step change in the use of composites, being the first civil aircraft where a majority of the structure was built from polymer composite materials rather than metals. Also important is the widespread availability of industrial carbon fibres which has led to a dramatic rise of the use of carbon fibre in wind energy blades. And with the BMW i3 programme, BMW and SGL have changed the perception of carbon fibre in the automotive industry. **SNW**