Recycling composites commercially

Glass fibre and carbon fibre reinforced plastics (GRP and CFRP) have excellent properties, but one barrier to the increased use of these materials is the lack of recycling facilities. Stella Job reports.

Cured carbon fibre waste prior to recycling. (Picture courtesy of ELG Carbon Fibre.)

Glass and carbon fibres are inherently energy intensive to produce and resins used in composites are almost all oil-derived. The 'composite' nature of these materials and the predominantly cross-linked matrices used are what give them such excellent properties, but at the same time make them difficult to recycle. Seeking to gain as much value as possible from production and end of life waste is a quest worth pursuing, but it is a quest which a great many have embarked upon and few have reached the goal.

Table 1 lists the companies of which the author is aware who, at the time of writing, are taking waste from the composites industry and recycling it into marketable products. Table 2 lists several companies which are close to this position. No doubt there are more, in addition to a good number of companies recycling in-house or in business to business relationships. For example, M-C-R, part of Groupe Plastic Omnium, have been recycling their clients' GRP waste as filler back into moulding compounds for many years.

This article celebrates those who have reached the goal and, though they may still be growing and developing, are commercially recycling composite materials.

Company/location	Materials recycled	Process/capacity	Recyclate market	Website/contact
CFK Valley Stade Recycling GmbH & carboNXT GmbH Stade, Germany	All kinds of CFRP waste materials	Pyrolysis, >1000 tonnes/year, launched in 2011	Milled 80-500 µm. Fibreball/ pelletised/chopped 1-100 mm (e.g. for PA, PC, PP reinforced compounds). Wet laid veil 10-30 g/m^2 (e.g. for surface optimisation, EMI shielding). Air laid nonwovens 200-600 g/m^2 (e.g. for RTM process for structural parts, SMC & BMC process).	www.carbonxt.de http://cfk-recycling.com
ELG Carbon Fibre, West Midlands, UK	Dry carbon fibre waste, carbon fibre prepreg waste, carbon fibre laminates	Pyrolysis process, 2000 tonnes/year recovered carbon fibre output	Chopped/milled/pelletised carbon fibre. Carbon fibre random mats and discontinuous fibre yarns. Preforms.	www.elgcf.com
Materials Innovation Technologies – Reengineered Carbon Fiber (MIT-RCF), South Carolina, USA	All kinds of CFRP waste materials	Pyrolysis, current capacity 2000 tonnes/ year recovered carbon fibre output (room for expansion)	Nonwoven rolled goods. Chopped fibre for compounding and long fibre reinforced thermoplastic (LFT) applications. Preforms (3-DEP™ process).	http://mitrcf.com
Reprocover, Belgium	Thermosets, including GRP with or without fibre reinforcement. Dry glass fibre waste.	Thermoset waste ground to max. 6 mm granules. 30% glass fibre flakes mixed with 70% thermoset granules, resin added, high pressure cold moulded.	Utility boxes, rail infrastructure products (e.g. cable tray covers), flower boxes, bins etc.	www.reprocover.com
Zajons Logistik, Melbeck, nr. Hamburg, Germany	Cured GRP 100% recovery guarantee (thermal recovery/ recycling)	Compocycle process. Shredded and mixed with RDF (refuse derived fuel) for use in cement kilns. Capacity 60,000 tonnes/year.	Used in Holcim cement kilns. Mineral content of glass and filler becomes cement feedstock, polymer content is burnt for calorific value.	www.compocycle.com
Procotex, Dottignies, Belgium, and Apply Carbon, Languidic, France	Dry fibres: carbon, aramid, PEEK and natural fibres etc.	Pulling, garneting, carding, drying, milling, precision cutting to length. Sizing of chopped fibre available from autumn 2014.	Milled (from 75 µm) and cut carbon up to 120 mm. Various natural fibre products. Aramids, cut 0.25 to 120 mm. Pulled fibres and carded tows. Various other technical fibres pulled/cut.	http://en.procotex.com

Table 1: Commercial composites recycling services for carbon fibre reinforced plastic (CFRP) and glass fibre reinforced plastic (GRP).

Here are the stories of two such companies.

ELG Carbon Fibre: the world's first commercial carbon fibre recycling company

I first met John Davidson, then Managing Director of Milled Carbon, in 2007 at a WINGNet meeting (a network for waste reduction in aircraft). At that point they had developed their first pilot-scale pyrolysis plant in the West Midlands, UK, and were soon to become the world's first commercial carbon fibre recycling company.

Milled Carbon changed name to Recycled Carbon Fibre in 2008 and was bought by ELG Haniel GmbH in 2011, becoming ELG Carbon Fibre (ELG CF). Davidson's career has been in carbon fibre manufacture and since moving on from Recycled Carbon Fibre in 2009 he works as an expert in manufacture of carbon fibre and PAN precursors through his company Carbon Fibre Technologies International.

"When we first started recycling carbon fibre composites we hadn't anticipated the level of success we came to achieve," says Davidson.

"Our first challenge was in determining the best process for recycling; very early on we fixed on pyrolysis, more because of my carbon fibre manufacturing background than any other reason. I decided to mimic part of the manufacturing process and devised a continuous pyrolysis process."

They acquired a second hand annealing furnace which they modified to suit their purpose. After mixed results to start with, they quickly learned the ideal parameters required to achieve their goals. With the process proved in principle, the next challenges appeared. One was to identify the properties of the recyclate and this was solved by their introduction, through WINGNet, to Boeing, which was exploring a means to close the lifecycle on their new Dreamliner aircraft. Boeing had the material tested at North Carolina State University and the findings were far in excess of what they had hoped for.

Company/location	Materials recycled	Status summary	Website
Extreme EcoSolutions, Netherlands	Cured GRP including whole products (e.g. boats)	Have started collecting production and end of life waste, working with selected partners in the transport and dismantling sector. The intention is to shred the GRP and grind to powder. This would be transported to Norway for recycling, initially as an additive for polyethylene film products in a process which is under development.	http://extreme-ecosolutions.com
Carbon Fibre Recycle Industry Co Ltd, Japan	CFRP waste	Utilising thermal decomposition by self-combusion process (6.7 MJ/kg-CF, 13.2 MJ/kg-CF), the company expects a recycling output of 1080 tonnes/year.	http://698.jp/cfri
Global Composites Recycling Solutions, UK	Cured GRP and glass fibre	Ground GRP and glass fibre is incorporated with other materials into Ecopolycrete. This is to be sold as a mix for polymer concrete type applications which can be precast or poured in place for railway sleepers, parking stops and other construction products. The material has a steel-like compressive strength and very high fire resistance. Expected to go commercial in Tennessee, USA, from September 2014, and soon afterwards in Northamptonshire, UK.	www.ecopolycrete.com
Hambleside Danelaw, UK	Cured GRP	Have developed a process for mechanically recycling GRP to retain fibre length. These fibres have been utilised to form reinforcements both as chopped fibre and in nonwoven recycled fibre mats. The fibres have been used in both thermoset and thermoplastic composites to form products for the construction industry. Experimentation has also been carried out in using the fibres with concrete and with rubber to enhance the properties of these materials.	www.hambleside-danelaw.co.uk
Karborek RCF, Puglia, Italy	CFRP waste	Pyrolysis process with energy recovery, to produce chopped/milled carbon fibres and carbon fibre felt. Capacity up to 1500 tonnes/year. The plant will be completed in October 2014, expecting to be in prodution from January 2015.	www.karborekrcf.it

Table 2: Near commercial composites recycling services.

Next they needed a continuous source of carbon fibre waste. This had been a concern from the beginning.

"I need not have worried," Davidson says. "Within a very short time we had to consider larger premises to accommodate the amount of material being offered to us."

This in itself led to the problem of knowing what was in the waste and trying to educate waste generators about what they could and could not take – an ongoing problem which all recyclers face. Though in this case, they also had to deal with the secretive nature of the industry. Most composites manufacturers do not want to reveal how they made the composite.

Overriding all this was the need to comply with environmental regulations. This was particularly difficult because the authorities did not know how to deal with this new process and simply didn't understand what happens when you burn composite resins, the environmental impact and how to monitor and regulate the process. This was a major headache throughout. Davidson speaks of trying to navigate the environmental laws of the time as a nightmare. It wasn't until Milled Carbon/Recycled Carbon Fibre moved to new premises in 2008 that they finally received a licence to operate.

But it did not end there. Alex Edge, current Business Development Manager at ELG Carbon Fibre, explains how they had to work closely with local authorities, the Environment Agency and the Health and Safety Executive to understand the risks of fibres released into the atmosphere in the factory. Initially they took a very conservative approach in terms of respiratory protection and personal protective equipment (PPE). Over time they have monitored parts per million of fibres in the air and, with effective extraction units and isolation of milling and shredding rooms, the communal areas are now clean and have very low dust levels. Staff and visitors can safely walk through the factory without suiting up in full PPE.

A barrier to development at the Coseley site which ELG CF currently operates is the electricity demand. The shredder and furnace put a high demand on the local grid and investment to improve the local electricity supply infrastructure would be high. While supplies can support the current equipment running at full capacity, ELG CF is assessing ways to generate power using heat recovery from the furnace. They can also avoid using the furnace to process dry fibre waste for the thermoset market, where keeping the size on the fibre surface is useful.

From very early on Milled Carbon concentrated on the end uses of the recyclate, collaborating on many government funded projects in an effort to create momentum.

Davidson comments: "I believe there is still resistance to using recyclate and there are obvious constraints. BMW are making great strides in including recycled carbon fibre in their iSeries cars and, along with Boeing and Airbus driving efforts to close the loop

The pyrolysis plant at ELG Carbon Fibre. (Picture courtesy of ELG Carbon Fibre.)

on their aircraft, there is considerable drive to recycle."

In the last year the waste coming in has boomed and the challenge to generate more markets is greater than ever. With aggressive marketing ELG CF could possibly bring in up to 10,000 tonnes of carbon fibre waste per annum, for which they would need three sites.

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As Edge explains: "The initial markets in milled and chopped fibres have proved to be quite volatile because of dumping and spot price deals. Moving into more sustainable markets is attractive, directed to specific products rather than the commodity market of milled and chopped fibres."

To do this, ELG CF has worked with OEMs in several sectors who have opened up their supply chains to develop semi-finished products tailored to the market need. These products maintain fibre length as much as possible to maximise the value of the fibres and hit a price point for customers which allows them to make substantial savings over virgin carbon fibre. While not applied to primary structures, for tooling or secondary structures these can displace lower value CFRP applications or improve properties where GRP has been used.

Such products include random mats, discontinuous fibre yarns and preforms. These are already available through toll manufacturers while development continues to meet customer requirements and gain certification, with a view to investing in equipment to manufacture in-house.

The recently appointed Managing Director, Frazer Barnes (since February 2014) has decades of experience in introducing carbon fibre in different applications and sectors. His approach is refreshingly open and they recently held an open day with trade association Composites UK which was well received.

ELG CF's story is a success story, though still in the making, with challenges that go far beyond 'simply' creating a process and a supply chain. There is plenty more to do in a market which is rapidly growing and changing.

Reprocover: Recycling fibreglass into useful products

"Ludo Debergh is an inventor," says Philip van Caenegem, who took over Belgian company Reprocover from Debergh in 2013. "He is triggered by things that do not work."

He went on to describe the way in which Debergh, already in his sixties, took on the challenge of finding a solution for recycling fibreglass and thermosets into cost-effective products. After selling his construction company, Debergh chose not to take a nice retirement home in the Mediterranean but instead invested his money and effort in perfecting the art of grinding, mixing and pressing this waste into useful products.

The main headache in the development of the process was to mix and press the dry mixture with the resin chemicals before the resin hardened. Debergh developed no less than 26 prototypes before creating a mixer which combines granules, glass fibre and resins into a slurry in just 1 minute, ready to be pressed in a mould. Reprocover filed a patent application for this remarkable mixer.

Reprocover started production in 2011 with manhole covers.

Debergh says: "Glass fibre plays a key role in Reprocover products, bringing high rigidity and outstanding load resistance. As an example, our 315 mm diameter manhole can easily withstand a heavy pressure load without damage. Working with 90% recycled materials can reduce the cost of existing cast iron solutions by a factor of

Level crossing panels including recycled GRP and phenolics from car parts. (Picture courtesy of Reprocover.)

five while providing much superior adhesion to asphalt and concrete."

The first customers were the Flemish Water Company and then the cities and towns of Liège, Namur, Bilzen and Landen who ordered planters, ashtray bins and mailboxes.

One of their major lines now is cable duct covers. The Reprocover product is about half the weight or the concrete equivalent, so just one man can lift and install the cover rather than two. It also eliminates the problem of a loss in transit of 5-15% of the concrete covers as they are so brittle.

Reprocover will take waste from manufacturers directly or through waste management companies for a fee which varies depending on the route. Van Caenegem noted that there are three perspectives from those who have waste which could be recycled. Many are happy for their waste to be recycled as long as it doesn't cost them more than sending it to landfill. For some, there is value to the company to see their waste recycled and so they are willing to pay more than the cost of landfill. Others see the waste as a resource and expect to pay less than the disposal cost to share in the value that is being realised by re-using the waste.

An example of the second perspective is from a company which makes polyurethane safety shoes. Reprocover can recycle the used shoes into street furniture. Recently this company has won two contracts because they were able to argue that their shoes were recyclable. There are several markets where the use of 'non-recyclable' materials is under threat or has already diminished, so in these cases, recycling is much more valuable.

The first challenge of building this business was to find a solution and some initial markets where products could be accepted and quality standards met. Then the company needed to go through the transition from starter to industrial phase. The investment to achieve this had to be found. Now they are in the phase of growing the business through finding the right products at the right profit margins.

A great deal of investigation and testing has had to be done to identify the properties of the material in relation to potential markets. For example the material could be used to make flooring for rail freight trucks, replacing wooden floors which are expensive and susceptible to moisture. The testing to qualify the material for this is onerous, and

The Reprocover process

In its factory in Henri-Chappelle in Belgium, Reprocover break, grind and sieve thermoset industrial waste into 6 mm granules. They can take thermosets with or without fibre reinforcement. A similar recycling process is carried out on dry glass fibre waste. These are mixed with each other in a ratio of approx. 30% of glass fibre flakes to 70% thermoset granules. The dry mixture is then mixed with polyols and isocyanate (at 8-10%) and poured out into moulds and pressed under 200 tonne presses, triggering off a chemical reaction (cold pressure process) whereby the chemicals polymerise into a polyurethane resin, binding the granules and glass fibre flakes.

The result is a very hard and strong material which is resistant to fire, extreme temperature variations, UV and chemicals. It does not corrode, has good slip resistance and is lightweight.

The material is 100% closed loop recyclable in the same process, as the thermoset resins do not lose strength when recycled over and over again as thermoplastics do.

Ludo Debergh invested €6 million in capital in Reprocover, in addition to further investment from other sources. The company is on track to break even by the end of 2015. They charge a gate fee to take waste that would otherwise go to landfill.

rail companies can be difficult to penetrate, but the market is potentially very large.

They can only compete if they take advantage of specific characteristics of their material. E.g. the skid resistance gives Reprocover's products an edge over concrete covers where people need to walk on them; inflammability is an advantage to replace rubber for rail crossings in tunnels.

"We don't talk about waste to customers," says van Caenegem, explaining that they develop products that are competitive with other materials regardless of the fact that they are made out of recycled materials. The bulk of the market is only interested in price and quality. The ecological element is irrelevant for procurement purposes, though recycling is considered a plus once a product is approved.

Future developments

It is interesting to see that all the processes which have achieved commercial status for recycling carbon fibre are based on pyrolysis. The companies active in this area seem to be focussing more on higher value products such as mats and preforms, to complement the chopped and milled fibre markets. The University of Nottingham, UK, continues to work on their fluidised bed process, working with sponsorship from Boeing. This is interesting because this process may provide fibres that are cleaner and easier to reprocess than those from pyrolysis.

There are at least six groups which are researching or have researched solvolysis-based processes for carbon fibre, which can gain more value from the resin chemicals in the waste, but none of these seems to be close to commercialisation at this point in time. Thermochemical processes have also been developed for GRP and three have been reported publicly in recent years. Heibei KNT was reported in January to have a recycling line under construction in Jizhou City, China. This is due to use a high temperature cracking and low temperature catalytic separation process to re-use glass fibre for functional parts or as high-temperature ground milled fibre. Resin products could be used as heavy fuel oil or refined to produce chemical raw materials. (This has not been included in the table as no further information is available.) Panasonic Electric Works Co Ltd built a pilot plant in Japan in 2009 to treat 400 kg per batch but is not near to commercialisation yet. SINTEF in Norway developed a process, but it does not appear to have been brought to market.

It will be interesting to see if these can be fully commercialised on an economic basis. One factor is that when glass fibre loses its size (as is the case with a thermal or chemical process), it also loses most of its strength. Strathclyde University, Scotland, has developed a process to regenerate the strength of thermally recycled glass fibre and is actively seeking partners to develop this, so perhaps this will provide a solution which can compete with virgin chopped glass fibres.

There is also continued interest in using ground GRP recyclate either in thermoplastics or in construction products with a thermoset binder. Reprocover are already successful in the latter. The Ecopolycrete material is another example, and Global Composites Recycling Solutions expect to be up and running before the end of the year in the USA and UK. Progress by Hambleside Danelaw and Extreme EcoSolutions may also find ways to gain more value from GRP waste than using it as cement feedstock, though Zajons are providing a useful alternative to landfill in the meantime with the cement kiln method.

The Båtskroten project in Sweden intends to take whole boats, recycle/re-use spare parts, and then recycle the GRP hulls. Båtskroten is an initiative with Stena Recycling to develop a process and a network for boat scrapping, hoping to start actively in the second half of 2015.

The trend is to seek higher value from recyclate, while balancing that against processing costs. The economic struggles of recent years slowed development for some companies, but now that we are seeing recovery and a high growth rate in the composites industry, the opportunities and the need for recycling will increase. ■

If you have any companies to add to our lists please e-mail RP@elsevier.com.

Further information

Stella Job is a freelance consultant in the composites sector and works part time as Supply Chain and Environment Officer for the UK trade association Composites UK.

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