A sustainable future for the composites industry

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Versatile, light, cheap, durable, and with seemingly limitless applications, it is no exaggeration to say that GFRP has revolutionised manufacturing across most major industries since its mass commercialisation roughly 50 years ago. Unfortunately, the same durability that makes GFRP the material of choice for so many products has also made the task of finding end-of-life solutions incredibly challenging.

Fibreglass has historically been designed to be durable, not recyclable. This has led to the mounting problem that composite industry manufacturers face today. Take boats, for example. Given that the fibreglass used in boat hulls (as well as in many other GFRP-based products) has a useful life of 30 to 40 years, Europe has already amassed 2 million tonnes of waste boat hulls. With no clear means of disposal, they clog harbours and litter waterways and shorelines.

The wind turbine industry faces similar obstacles, with waste turbine blades accumulating at an alarming rate. The University of Cambridge has calculated that with recent expansion of wind energy —which is good news in most respects— there will be 43 million tonnes of waste wind turbine blades by 2050. This is a "green" technology that poses a waste problem that is sizeable, in more ways than one. These are estimates from just two industries which rely heavily on GFRP, and the figures don't factor in GFRP production waste that piles up on factory floors as manufacturing surges to meet unprecedented demand for new boats and wind turbines.

What options are available for the composites industry?

Today, the most common means of disposing of GFRP waste are neither desirable nor sustainable. One can either pay to have it landfilled, which pollutes both the soil and the water table with microscopic plastic particles, or ship it to cement manufacturers to incinerate in kilns for energy production (GFRP burns at a very high temperature), which releases toxic emissions into the air.

All the while, key stakeholders are turning up the pressure. Governments are imposing more stringent environmental regulations — hiking up disposal fees on dwindling landfill space and establishing ever-higher emissions standards. At the same time, the market is becoming more environmentally savvy, rejecting what they see as half-measures or greenwashing and demanding "clean" products and technologies across all sectors. More than ever before —whether for plastic bottles or sailboats— consumers are asking the question of themselves and of their preferred brands: where will this item end up when I'm done with it? It's a question to which the composites industry has had no satisfactory answer. Until now, that is.

Let's try again

First, a bit history, as the lack of a solution for GFRP recycling certainly hasn't been due to a lack of trying. Former attempts have included mechanical, chemical and thermal approaches. But the "holy grail" of recycling GFRP has been to successfully separate the resin from the glass fibre in a way such that the component elements might be reclaimed, revalorized and reused. Shredding, a mechanical approach, saves space in landfills, yet yields only low-value outputs. For example, shredded GFRP can be used as construction filler, but many lower-cost and/or cleaner alternatives exist.

The chemical approach is referred to as solvolysis, and it consists in dissolving the resin surrounding the glass fibre. But as the name suggests, the process involves a large amount of solvents, with all the challenges associated with sourcing and disposing of them, which can represent a threat to both human health and the environment in general. It also leaves a good amount of resin residue within the fibres, severely limiting their value for future reuse.

The third approach involves a thermal process called pyrolysis, which uses heat to vaporise the resin and separate it from the glass fibres, with the resulting outputs being gas, oil, and the reclaimed fibres. This seemed to be the most promising path and in fact was performed successfully in small batches in laboratory settings.

However, none of the past efforts to use pyrolysis proved economically viable. This is because past pyrolysis attempts were applied to shredded composites – which meant that even with the resin gone, the resulting recovered mass of shredded fibre retained very little potential value to manufacturers. The result was that no solution was developed for deployment at an industrial scale, with pyrolysis written off by composite experts everywhere as a nonviable solution.

Pyrolysis and post-treatment

The term pyrolysis refers to the thermal decomposition of composite materials in an atmosphere without oxygen. When applied to GFRP, this process separates the resin from the fibres, with the heat rearranging the molecules and breaking the covalent bonds within the resin, allowing liquid and gas phases to form.

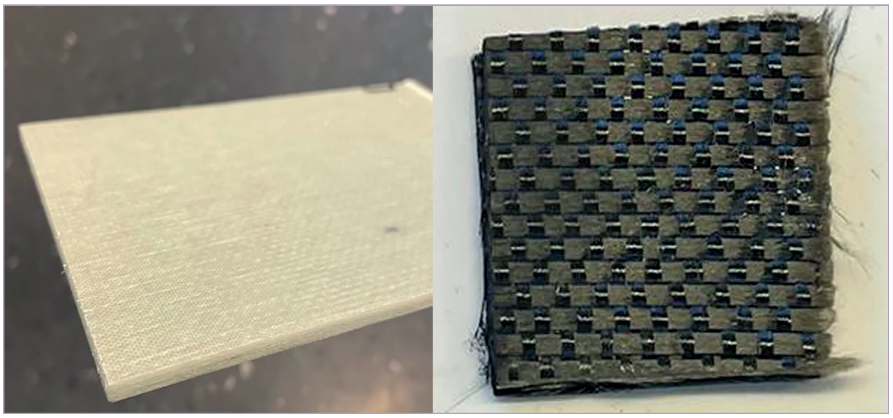

Fig. 2: Glass fibre reinforced epoxy sample before (left) and after (right) pyrolysis; the GFRP is composed of 10 sheets of woven glass fibres; after pyrolysis, the fibres are covered with a residual layer of amorphous carbon © Composite Recycling

Unlike alternative combustion processes that use O_2 and which turn most of the matter into CO_2, pyrolysis generates very little CO_2, and the products obtained, such as pyrolysis oil and carbon black, have many industrial applications. More importantly, liquifying the resin makes it possible to recover high-quality glass fibres afterwards (Figure 1).

When the glass fibres are retrieved from the reactor, they are covered with amorphous carbon. However, the overall structure of glass fibres remains unchanged: the woven fibres, after pyrolysis, keep their initial structure (Figures 2 and 3).

Meanwhile, the resin component of GFRP is transformed into hot gases, some of which are condensed into a liquid component. This liquid pyrolysis oil, can

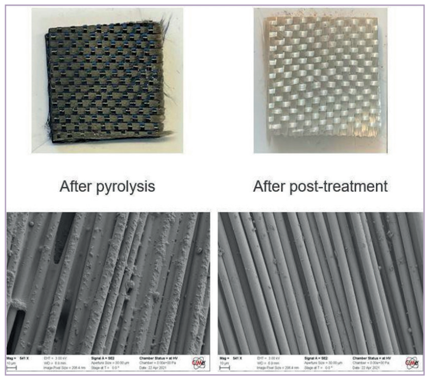

Fig. 3: Electron microscope images show the result when the amorphous carbon is removed, leaving the original fibres clean and intact © Composite Recycling

be used as fuel like diesel but better still, since it contains a high proportion of chemical compounds, it can be used in the manufacture of new, decarbonated plastics (Figure 4).

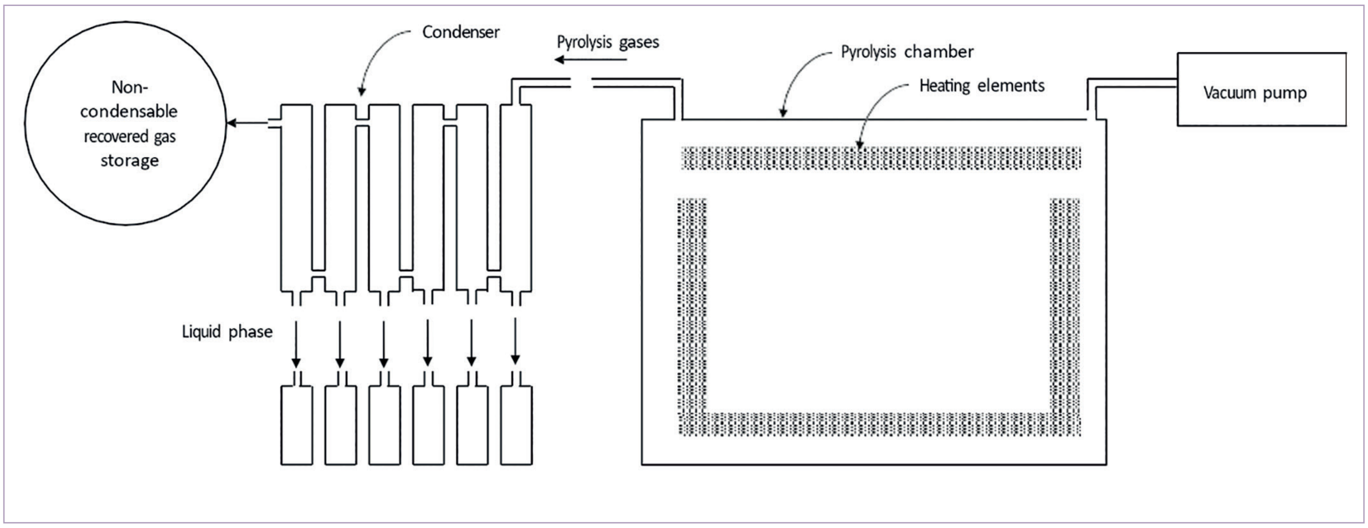

Fig. 1: Schematic diagram of a pyrolysis system

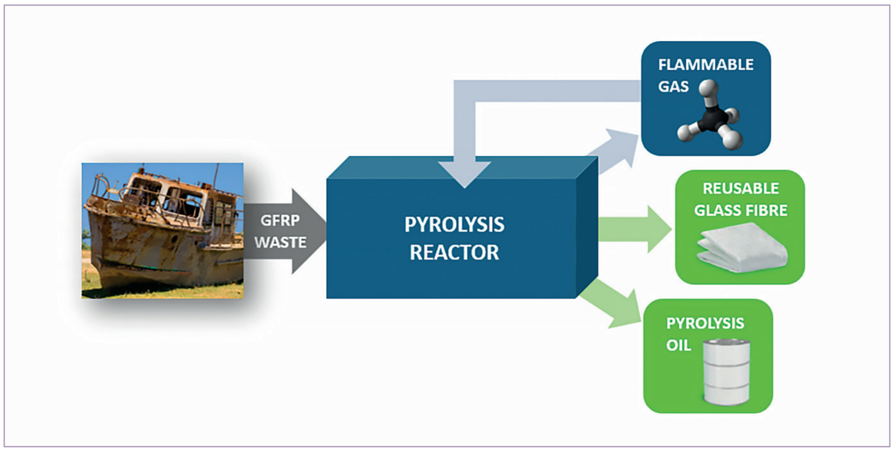

Fig. 4: Composite Recycling's process map © Composite Recycling

Enter Composite Recycling

Swiss-based newcomer Composite Recycling (CR) has developed a new approach comprising three key improvements upon past pyrolysis efforts, which have made all the difference.

The team started with a single-minded focus on recycling only composite materials, for example boats –or, more specifically, the fibreglass hulls of boats. Limiting inputs to GFRP only, and designing a pyrolysis reactor specifically for it yields much more consistent outputs. The resulting gas and oil outputs, for example, are of a high-enough quality that they can be treated and sold on commodity markets. Precisely calibrating the pyrolysis process so that outputs can be easily sold on existing markets or used within a customer's existing process offers a clear benefit versus other recycling businesses who have had to create new markets or applications for their outputs.

Then, rather than shredding the GRFP waste before pyrolysing it, CR cuts the waste into large sections (1.5 m x 2 m) and employs a static treatment, which enables them to recover the post-processing glass fibres almost entirely intact. This preserves much of the mechanical properties, and thus the value, of virgin fibre.

Together with the Advanced Composites Laboratory of the Swiss Federal Institute of Technology in Lausanne (EPFL), CR has developed a patent-pending post-treatment process that further cleans and restores the reclaimed fibres. Following this treatment, the glass fibres' integrity is so nearly completely maintained that GFRP manufacturers can reincorporate it into new fibreglass and add it to their product ranges.

This means they can provide end-of-life solutions to their own clients who can, in their turn, offer "green" GFRP-sourced products to end-consumers.

As an impressive finishing touch, the company process captures the gas that is released during pyrolysis, using it to power the reactor and making the process energy self-sufficient. This has the dual benefit of further improving the economics of the process, while also reducing the carbon footprint.

In this way, CR's innovative approach to pyrolysis has rendered the process economically viable, and industrially scalable, for the first time. A sustainable end-of-life solution has come to the composite industry at last.

A fresh go-to-market approach

Beyond the scientific approach the company has pioneered, its business model also features innovative new technology and go-to-market strategies calibrated to each customer's specific needs and the particular type of waste to be treated.

APER: a test case in boat recycling

In Europe, around 2 million tonnes of boat hulls are waiting for a disposal solution. Environmental regulatory pressure is becoming extreme as the European Union extends the obligation for manufacturers to find an end-of-life solution for their products. In France, a world leader in recreational boat building —and a country where 200,000 tonnes of waste boat hulls await treatment— this obligation was applied to boat builders in 2019. Meanwhile, economic pressure is also mounting to free up congested harbours. With 12,000 new recreational boats registered annually in France, and waitlists for harbour spaces growing ever longer, berths blocked by wrecked or abandoned boats represent a significant economic loss for harbour owners. It isn't a surprise, then, that the French government has taken the lead in boat recycling and has organised the world's first state-level boat deconstruction programme.
With the collection and dismantling of end-of-life boats funded through taxes on new boats and a yearly registration tax, the Association for Eco-Responsible Yachting (APER) has 30 boat deconstruction centres across the country. At these sites, the metal components (engines, keel, mast, etc.) and the wood and fabric elements (interior fittings) are removed for resale or recycling. Then, the boat is "depolluted" —meaning toxic elements like oil, gas, and batteries are removed and disposed of sustainably. The only remaining piece of the boat with no recycling solution —the "missing link" for APER— has been the fibreglass hulls, which up to recently have been crushed or shredded, and then either landfilled or burnt in cement factory kilns for energy.

That all changed with Composite Recycling's fibreglass recycling solution and the exclusive agreement signed between the two parties at the Paris Boat show in 2022. From 2024, APER will finally be able to offer the full recycling solution to boat owners and "close the loop" on boat recycling in France.
Meanwhile, discussions are underway with the European Boating Industry in Brussels to develop end-of-life policies programmes at the level of the European Union.

Fig. 5: The mobile recycling units will fit into a container like this one, to ensure access to any waste storage location

Consider the above case of the 2 million tonnes of end-of-life boat hulls, now collected in harbours or dumped along rivers and on the coasts, in need of recycling. To tackle these, CR has developed a pyrolysis solution that is mobile, building a reactor into 40-foot containers which can be easily trucked in from location to location to batch-process and clean up the boat hull waste on the spot. CR's mobile unit being towed in to treat the large quantities of boat waste occurring after hurricanes have passed makes for an inspiring prospect indeed (Figure 5).

Meanwhile, the GFRP production scrap on aerospace, boating or automotive manufacturing sites presents an entirely different challenge. To treat this type of high-quantity and very homogenous waste, CR proposes an on-site, stationary reactor, one which can output reclaimed glass fibres that the manufacturer could potentially reinject into their own manufacturing processes.

Looking ahead to the future, CR plans to treat extremely massive wind turbine blade waste on a continual basis within a larger, semi-permanent configuration that can be rotated into place when wind farms are being upgraded.

In all the above cases, the company's strategy is to perform pyrolysis on site, as closely as possible to the need (at harbours, factories, shipyards, etc.).

The benefit of this is multi-fold. First, it's more convenient for the customer. Second, composite waste often comes in extremely bulky forms: boat hulls, wind turbine blades, airplane interiors, etc. It is far cheaper and more efficient (not to mention more ecologically palatable) to transport a single container to the location of the waste for treatment than to transport large quantities of oversized waste over many kilometres to a distant central site. Last but not least, it is illegal to export waste across borders. But once it has been pyrolysed, composite waste is actually transformed, with the outputs considered new raw materials, which can thus traverse borders without problem. This means that CR's solution is ready for global deployment from the outset.

After processing on site, the resulting output material from all pyrolysis recycling units —much lighter and less voluminous than the original GFRP waste— is shipped to clients (fibre weavers producing mat, chemical firms using pyrolysis oil, etc.). □

Closing the loop on the composites industry

Today the company has moved into the industrialisation phase for their solution. Two technology partnerships have been formed to produce the first mat containing reclaimed fibres with French-based composite manufacturer Chomarat, and world-leading boat manufacturer Groupe Bénéteau, an end-user of the mat. The company plans to deploy the first industrial containerised pyrolysis units in early 2024 in western France, where they will treat boat waste in partnership with Groupe Bénéteau and the French government boat deconstruction agency APER.

Meanwhile, given their high visibility (highlighted when they won the JEC World 2023 Startup Booster Award for Process and Manufacturing, earlier this year) and the optimism that this new solution has inspired across the composites ecosystem, companies across many sectors have reached out requesting CR's services, both for waste disposal as well as to explore end-of-life solutions for their own products.

The first step for these interested clients is to submit their waste products for testing with CR's pyrolysis process, to determine their recyclability potential and evaluate outputs and associated potential marketability. Importantly, these tests enable companies to demonstrate that their products are recyclable to internal and external stakeholders.

"*Fielding these requests has given us a fascinating view inside the composites and adjacent industries and an appreciation for the incredible pressures that so many are facing as they race to find sustainable solutions,* says CR CEO Guillaume Perben. *It's crazy to think that it all started with me worrying about what we would do with our family sailboat when the day came. Now, we are thrilled to be able to accompany and support companies in developing truly sustainable end-of-life solutions for their products.*"

More information:
composite-recycling.ch