NATIONAL COMPOSITES CENTRE

Sustainable Composites
A PARTNERSHIP BETWEEN THE NCC AND CPI

CASE STUDY

Reducing the environmental impact of composites in manufacture of wind turbines

The National Composites Centre (NCC) has identified alternative bio-based feedstock resins with the potential to enable more sustainable manufacture of wind turbine blades. This has been investigated in the Bio-bolster project, which has been funded by the Sustainable Composites Partnership, a collaboration between the NCC and CPI. The NCC and CPI are two of the seven centres of the High Value Manufacturing Catapult, working with industrial, academic and government partners to develop sustainable composites by 2040.

Challenge

There is a need to reduce the whole environmental impact of wind turbine manufacturing. An important part of this, indeed an ambition from the industry, is to explore the use of alternative feedstocks such as bio-based resins. The reason for this particular emphasis is that there is currently a perception that these bio-resins are more expensive and have lower performance in comparison to the more traditional epoxies.

Other drivers include strong public interest in green solutions and regulation, such as the UK's net zero strategy. Supply chain issues are also important as there is a need to diversify feedstock sources.

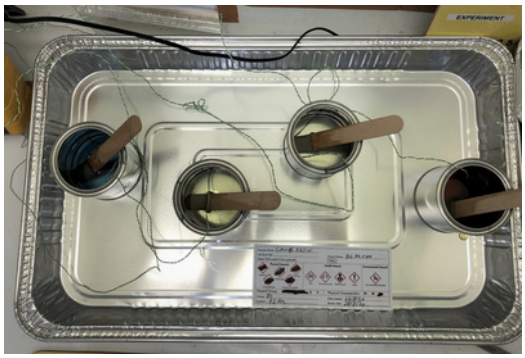
Alternative materials wind blade tip demonstrator

This project has investigated the processability and mechanical performance of bio-based resins to understand their current suitability for the wind turbine blade market, and therefore their potential to help reduce the environmental impact of the wind industry.

On a global scale, around 14,000 wind turbine blades are set to reach the end of their usable life within two to three years.

Innovation

The NCC set up project Bio-bolster to meet this challenge head on. The first step was to understand the existing market to select a baseline epoxy that was widely used within the wind industry. Following this, three commercially available bio-epoxies were selected, and their performance, processibility and sustainability credentials were compared to the industry baseline.



Gel point tests

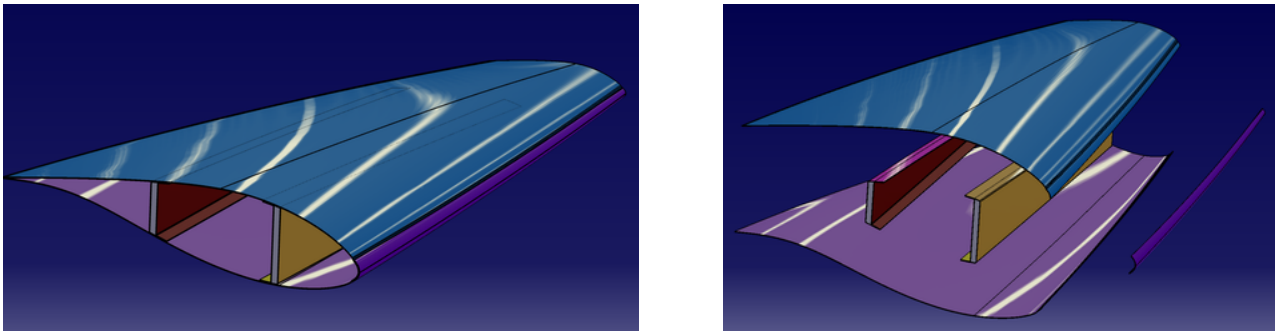
In line with industry feedback on challenges experienced within product manufacture, the NCC investigations into processibility indicated a couple of current challenges with bio-epoxies. Gel point tests revealed that the bio-resins evaluated had a higher tendency to exotherm when compared to other resins: one reached a temperature of almost 180°C, though this reduced to 50°C when combined with fibre in an infusion (a 3mm glass fibre panel).

This will need to be considered from a health and safety point of view, especially when handling large quantities of resin. Furthermore, the working time possible was lower with bio-based resins which may have implications for infusing larger structures, such as wind turbine blades.

DMA Testing indicated that the glass transition temperature of the bio-based epoxies was lower than the baseline, and therefore these resins may offer a reduced thermal tolerance at elevated temperatures, though this may not be as important for wind turbines. However, one of the bio-resins did have the shortest processing time, both infusion and post-cure, which may help to save time, energy and cost if deployed across wind turbine fleet.

In terms of overall manufacturing quality, two of the three bio variants produced panels of equal quality to the traditional epoxy resin, as confirmed by NDT. The resulting mechanical properties also showed promise when compared to the baseline. Properties were matched and in some cases were exceeded for compressive modulus, inter-laminar shear stress, in-plane shear stress and flexural modulus. This indicates that bio-based epoxies show great potential to replace traditional petrochemical based epoxies in the right applications.

Water take-up was higher in the bio-based epoxies (2-2.5%) than the baseline (1.5%) when conducting DVS trials on neat resin samples at 80% RH. This trend was also observed in water immersion trials of composite samples for 168 hours. This may not impact the wind industry however, as turbine blades are coated to protect the blade materials from the environment.



3D Blade Design

The sustainability of the bio-resins was also considered. The industrial interest in bio-resins is based on the potential for future decarbonised feedstocks, whereby the central arguments lie on the utilisation of waste bio-products and/or associated carbon sinks provided by the biological growth phase.

Whilst work is still on-going to evaluate the credibility of low carbon feedstocks, it was recognised that although they could support transition to net zero, they do not by themselves provide any end-of-life advantage over existing thermosetting systems in terms of waste management. This presents a key opportunity for the UK supply chain – to establish how fair carbon accounting comparisons can be drawn between material supply chains and redesign materials for end-of-life management.

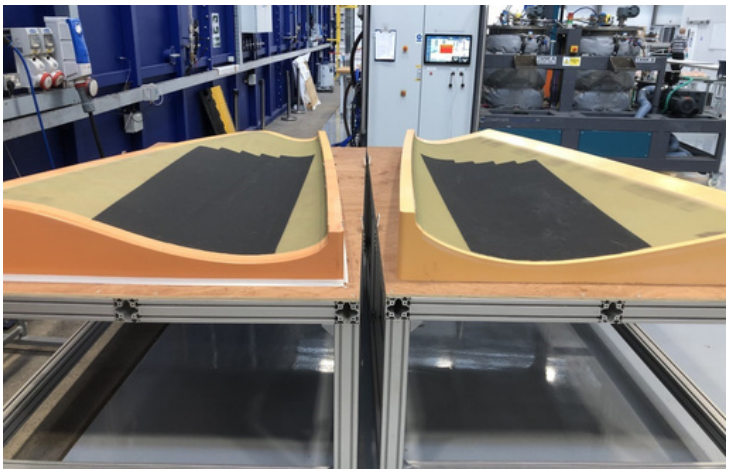
Result

- The bio-based content is limited to 40% and they are produced by natural sources or as co-products of other industrial processes.
- The bio-resins possess mechanical properties that are comparable to baseline resins.
- There is a tendency to exotherm which has implications on health and safety, manufacturing, and tooling material selection.
- DMA testing showed that the bio-resins offer a lower thermal tolerance.
- The bio-epoxies take up more water that the baseline across every humidity tested over a week period.
- The bio-epoxies have the potential to reduce embodied carbon within a composite system; although there is a need for both verified data and end-of-life solutions to be explored.

Impact

The NCC's long-term goal is to support industries transition from producing petrochemical based, non-recyclable products to environmentally friendly composites. This is to ensure the acceleration of innovation in an industry that produces a large quantity of waste. As more blades reach the end of their operational life, they will have to be replaced with a more environmentally positive alternative.

This project has opened the door for the future production of wind turbine blades that are made with sustainable composites. It has shown that using bio-resins does have potential. Some aspects of their performance can exceed traditional epoxies, such as mechanical.



Blade in manufacture

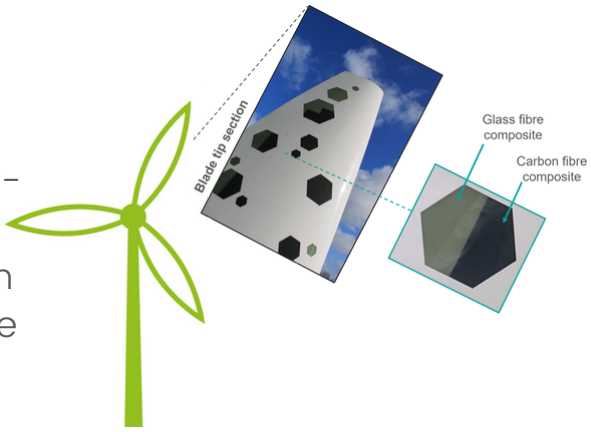
Bio-bolster is an important stepping-stone to make the use of bio-resins a viable alternative to traditional epoxies a reality. It has brought the use of these resins a step closer, though with still a significant amount of work to do before reaching the ultimate goal.

What next?

The various tests conducted by the NCC provides evidence to show that the bio-resins are competitively viable within the wind turbine blade industry. For future testing, the tests will have to be scaled up to explore how the bio-resins would perform in larger structures.

The NCC are also keeping in mind that due to the higher price of the bio-resins, the team must find a method to incorporate the composites in the supply chain development of the industry. The suppliers of the bio-resins are confident that they can deliver product that the industry needs in the volume it needs.

Another aspect of this project was to explore the sustainability of the materials in terms of its embodied carbon and the end-of-life management. The NCC team is building its life-cycle-assessment capability with a vision of easily accessible materials sustainability data. For end-of-life management, the NCC has launched a parallel programme exploring bio-derived thermoplastics in collaboration with academic institutes to investigate more inherent end-of-life benefits; as well as the continuation of recycling projects across its core and commercial work to support the development of a UK composite recycling supply chain.



Composite blade concept (coated by TJC Design)

Crucially, further investigation is needed on processability such as investigating different hardeners, especially for larger and thicker structures. This is currently underway in the Bio-Cure project (Sustainable Composites Partnership) which aims to investigate the challenges associated with processing window highlighted by Bio-bolster.

> “This project has enabled the NCC and CPI to manufacture the UK’s first wind blade tip from bio-based and recycled materials, and begin to drive a step change in low carbon materials and manufacturing.”

Annabel Fitzgerald
Advanced Research Engineer, National Composites Centere