AMRC Composite Centre
Case Study

MASTRO: Self-curing composites cuts energy usage by 99 per cent

Challenge

To develop a step-change in the curing of aerospace and high-end automotive composite components by establishing a new process, built around electrification, which is more efficient than ovens or high-pressure autoclaves.

Background

Manufacturing of composite components currently requires high temperatures for a set time to solidify or cure the resin. This is completed in ovens or autoclaves, using material manufacturers' prescribed temperature profiles, which can at times, exceed ten hours.

These heating methods are slow and inefficient: heating up the air in the chamber, then the tooling and consumables, and finally the component. This slow rate of heating and lag in the system is why the designed cure cycles are slow, to ensure that there are no hotspots and the composites do not have an exothermic reaction, which can overheat and damage the part. Due to these inherent issues, it is difficult to increase the efficiency of these processes significantly.

Through MASTRO, a three-year Horizon 2020 project, the University of Sheffield Advanced Manufacturing Research Centre (AMRC) has developed multifunctional composites with three different functionalities to move to electrification and reduction in carbon emissions.

Working with MASTRO project partner Embraer, these smart functionalities – self-curing, self-sensing and self-anti-icing – have been implemented into aerospace and automotive demonstrators.

Example of the leading-edge demonstrator during the infusion and curing process, showing the electrodes required for self-curing.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 760940.

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Innovation

Self-curing, also known as direct electric cure, is a composite curing method that heats up the component using the Joule effect - the physical effect by which the passing of current through an electrical conductor produces thermal energy.

Carbon fibres in the component are electrically resistive and can be used as a heating element. These are directly connected to a power source and therefore heat only the component, where the heat is required for curing, rather than the whole environment around it. This increases the power efficiency of the process.

Initial capital expenditure is reduced significantly, rather than having an oven or autoclave the size of your component, self-cure only requires a power supply, a basic control system and low-cost extra consumables.

The method was developed over the project from small lab scale coupons, up to the demonstrator scale, which measured 200x70 cm and was 16 plies thick.

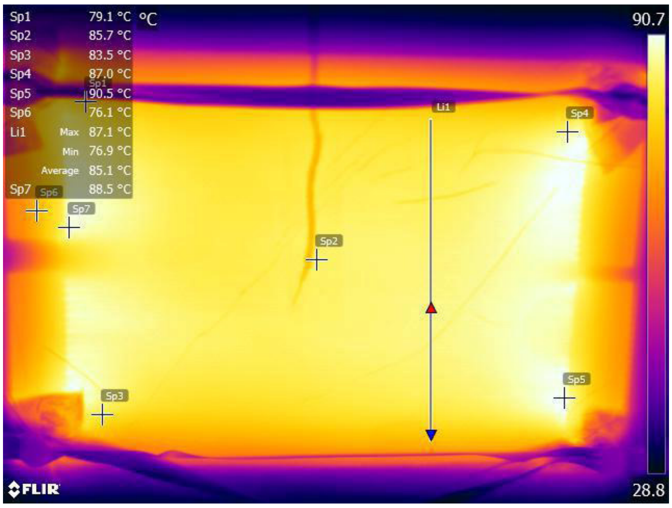
An example of the full electric cure setup, showing the copper electrodes in the component, connected to a computer-controlled power supply.

Results

In MASTRO, this technology was developed from small scale panels up to a two-metre-long, leading-edge section, with Nomex stiffeners included, to be representative of an industrial geometry for aerospace or automotive. It was possible to cure both pre-preg and resin infusion components successfully.

Energy usage for the same part cured in an oven was reduced by 99 per cent, significantly reducing the carbon footprint of this manufacturing step. The degree of cure of the self-cured part was within 10 per cent of the oven cured samples, with some further work required to increase this.

Capital expenditure was reduced by 90 per cent using this method, which meant that the process was safer, with the heating system being more responsive to any exothermic reaction and being able to dissipate the heat quickly.



Infrared image of self-curing, showing the temperature distribution over the carbon fibre component during heating process.

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Impact

The project has demonstrated that self-cure is a viable alternative to oven and autoclave curing for carbon fibre components for both aerospace and automotive. This method has the potential to make high performance manufacturing more accessible to a larger range of industries. It is possible with the existing developments to reduce energy consumption and equipment costs of simple composite components by 99 per cent and 90 per cent respectively.

With further research to increase the relevance to industry, there is opportunity to increase efficiency, reduce cure times further and increase the degree of cure to match existing manufacturing methods. We are actively looking for collaborators for further grant funded research.

Another benefit is the scalability of the technique, as there is theoretically no limit on the length of the component which can be cured using this method. This means that high aspect ratio aerospace components such as a leading edge, could be manufactured in one shot, rather than being manufactured in pieces and bonded separately later.

> This manufacturing method has the potential to make high performance manufacturing more accessible to a larger range of industries.

The self-cure process is applicable for other industries away from aerospace. Within the project a motorsport bumper was cured, which had a more complex geometry with cut-outs for headlights and an air intake. Other examples of industrial applications include: nacelles, automotive panelling, I beams, stringers, filament wound pressure vessels, heated tooling, wind turbine blades, bridge sections, masts, pipes, modular structures and on-site manufacture.

The final demonstrator after curing, once the manufacturing consumables have been removed.

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