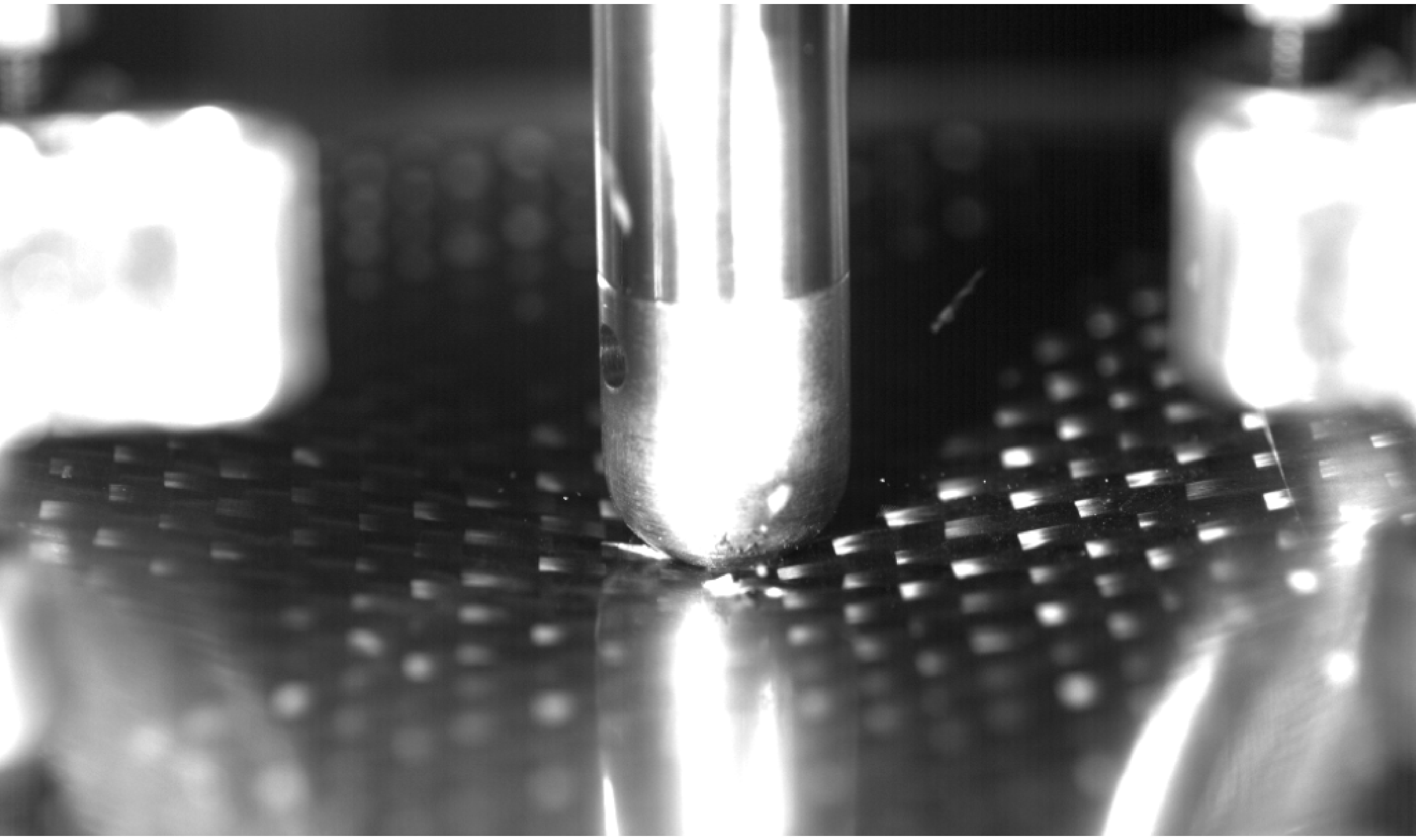
The University Of Sheffield. AMRC Advanced Manufacturing Research Centre

AMRC Composite Centre
Case Study

MASTRO: Detecting barely visible damage with self-sensing carbon fibre components

Challenge

To develop a self-sensing method, through the integration of a flexible printed circuit board (PCB) into carbon fibre reinforced plastic (CFRP) components early in manufacture. This electrical resistance-based sensing method can detect barely visible impact and puncture damage in aerospace composites – to make the use of carbon fibre in aerospace and automotive a safer and cost-effective choice.



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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Background

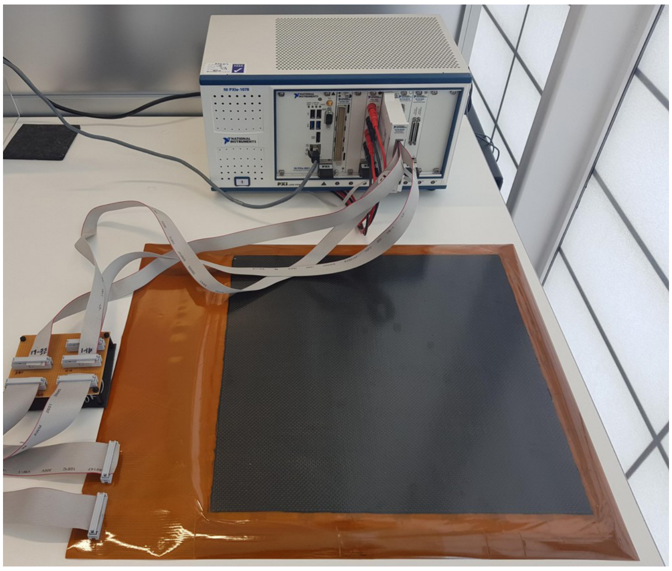
Carbon fibre composites are being used more frequently in aerospace and automotive applications over aluminium, due to it being lightweight and high strength; - however due to the epoxy in the composites being brittle, they are prone to being damaged easily by impact events.

One issue in carbon fibre composites is called barely visible impact damage (BVID). The surface impacted suffers little damage - but on the reverse face of the impact - a lot of strain occurs and can lead to significant damage later on. If not detected and repaired at an early stage, this damage can increase in size and lead to more costs to repair. In the worst cases, this can lead to the catastrophic failure of the component.

For the aerospace and automotive sectors, a key aspect of reducing emissions is the electrification of the propulsion systems, and electrification of ancillary systems that have previously relied on heat provided by the burning of fuel in jet engines and internal combustion engines.

Increased use of composite materials in more areas of aircraft and cars has led to a requirement of these ancillary systems being compatible. In this work, the move to composite materials has given an opportunity to use the conductivity of the fibres as a detection method, making the change from metallics to composites have less impact on the manufacturers and operators of these vehicles.

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 in an aerospace demonstrator.



The initial test setup, showing the resistance data acquisition system and the flexible PCB embedded into the composite panel.

Innovation

Self-sensing is a damage detection method which monitors the electrical resistance of the carbon fibres in the component, looking for changes caused by impact damage. Carbon fibre components are a network of resistive carbon fibres which change in force in response to strain when fibres are broken, leading to fewer electrical paths and increasing the overall resistivity.

To take advantage of these properties, many resistance measurements must be taken over a component, to build up an image of the damage.

A flexible PCB was developed that could be embedded into carbon fibre components at the manufacture stage. This allowed for electrical resistance monitoring all over the component and BVID as well as puncture damage to be detected without external inspection techniques.

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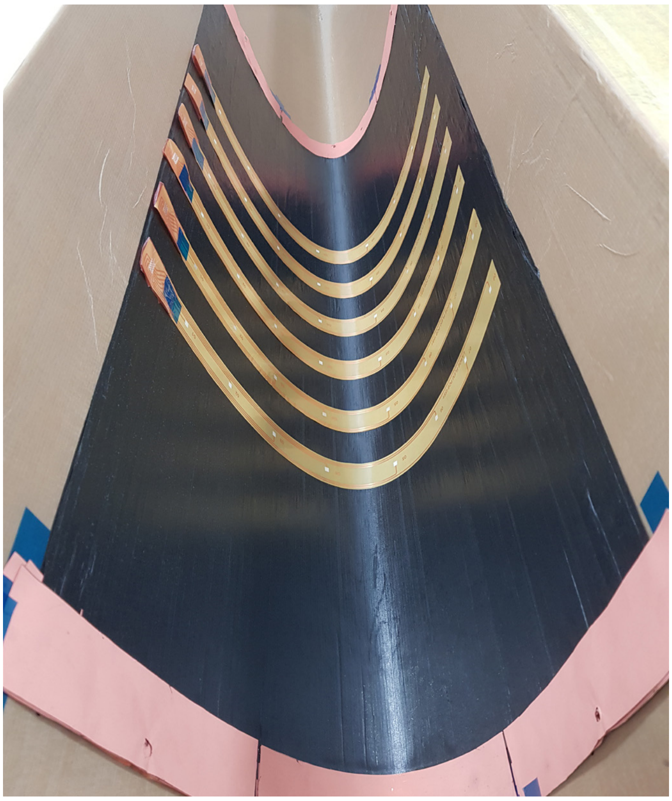
Results

A small-scale development PCB was tested with a variety of different resistance monitoring techniques on pre-preg and infusion composites and in a number of positions in the layup. Various zonal scanning techniques were tested from literature, to understand which technique was best suited to be scaled up into the MASTRO leading edge demonstrator.

Once the final self-sensing method had been determined, a modular PCB was developed that could be scaled along the full length of the two-meter-long, leading-edge demonstrator. Three final tests were completed and compared, embedding the PCBs, and bonding them on the surface with silver and carbon nanotubes (CNT) conductive resins.

In the final aerospace and automotive demonstrators, it was possible to detect BVID on the component in multiple locations, with high accuracy. Conductive interfaces such as the silver adhesive were the most effective, highlighting the importance of this processing step going forward. Repeatability of the technique is a concern, with false negatives and excessive noise appearing in some of the tests.



Final demonstrator during manufacturing, showing modular self-sensing PCBs being laid up equidistant apart, to provide high density of electrodes to ensure the system is sensitive to damage.

Impact

The accuracy of this method and ability to detect the location and severity of the impact shows that self-sensing is a viable method for CFRP structural health monitoring (SHM) in the future. More research is required to increase the repeatability of the method and the sensitivity of the location and severity of the damage.

Having the ability to detect damage in composites in damage critical zones will give a significant advantage to any operator using this technology. Operational costs of aircraft will reduce, as maintenance can be in reaction to damage, rather than scheduled at set intervals where it may not be required. Safety of the aircraft will be increased, as damage can be repaired immediately after it occurs, rather than after a set time during scheduled maintenance.

Composite repairs for automotive components will be easier when location and severity is known when the impact occurs, without the requirement of expensive non-destructive testing methods that require training and expertise to use correctly.

Self-sensing in its current form has the potential to be developed into a full component impact detection system for composites, however it is most likely to be a complementary technology to existing ultrasonic bases SHM systems. Where existing systems listen for damage within the composite, this method directly monitors component properties, which in damage critical areas is a valuable tool.

This method has potential to be used in other areas, for example: Automotive bumpers, monitoring strain of structural CFRP in civil, automotive and aerospace and SHM of leading edges of wind turbine blades.

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