Closed Loop Liquid Resin Infusion

4G Data Acquisition and Visualisation

DATA ACQUISITION AND VISUALISATION

Industry Challenge

Liquid resin infusion (LRI) is a process used by the aerospace, automotive, marine and many other industries to create composite components. These can range from boat hulls, to full aircraft wings, such as on the Airbus A220. It offers higher rate and lower cost production compared to other methods used to make composites (such as prepreg moulding, which has higher material costs, and longer processing times). The technique however is highly dependent on the skill of the operator, is very manual, and often produces many scrap components when developing new parts.

As industry grows its use of LRI, there is a need to improve the process to enable parts to be made 'right first time' and 'right every time' - lowering the cost and time of developing new components, and reducing the environmental impact of composite production by generating less scrap.

These improvements to LRI composite manufacturing can be achieved through data analysis and automation of the LRI process by the application of digital and 5G technologies.

The Closed Loop LRI programme was broken down into two phases of development. Phase 1 was the development of the data acquisition and visualisation systems, demonstrated on 4G, and is the focus of this case study. Phase 2 will develop the control systems and demonstrate acquisition, visualisation, and process control on 5G.

Approach and Innovation

The LRI process is complex with many variables effecting the quality of the final part. To be able to control these variables the first challenge is to monitor them, this is known as data acquisition. This data can then be visualised back to the process operator so they can see what is happening, and if necessary, alter the process to improve the part quality.

For this use case, resin arrival sensors were used to monitor the movement of the liquid resin as it flowed through the part – a key variable that effects the mechanical properties of the final composite. Without sensors it is difficult to track the resin flow (particularly if the manufacture is being done inside an oven).

Utilising the National Composite Centre's (NCCs) secure 4G network, a system was designed that could monitor the resin flow and wirelessly send this data back to the 4G core servers. The servers also hosted a visualisation application that displayed the data back to the operator.

This visualisation system is accessible by any PC or PC type tablet (such as a Microsoft Surface), allowing users to see the data from anywhere. For the manufacturing test case conducted, the visualisation app was accessed using a laptop.

All of the primary data communication was achieved using Messaging Queuing Telemetry Transport (MQTT), a lightweight messaging protocol used widely in the Internet of Things (IoT). The design and flow of data within the system is shown in the system architecture diagrams in Figure 1.

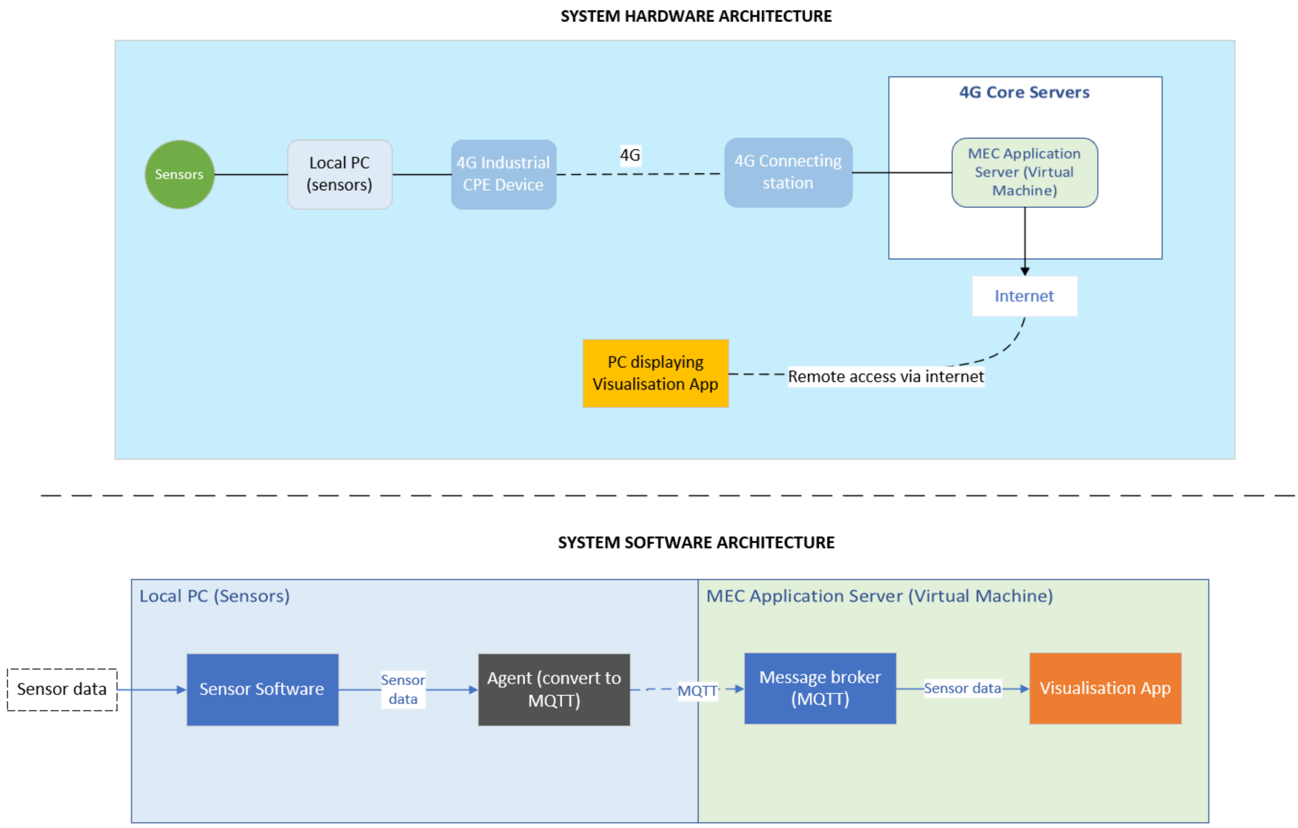

Figure 1 - System hardware architecture (above), system software architecture (below)

A room temperature infusion using a silicone bag was selected as the test for this use case. The sensors used were ‘resin arrival sensors’; advanced instruments that can detect when resin reaches a certain point during the infusion by monitoring a change in electrical resistance. Three in-bag sensors monitored the flow through the part, while four in-line sensors tracked the resin as it left the part.

The data from the sensors was displayed to the user via the visualisation app (in Phase 2, this data will be used to control the opening and closing of outlets). Details of the manufacture set up, sensor arrangement, and visualisation app can be seen in Figure 2, Figure 3, and Figure 4 below.

To the authors knowledge, this type of data acquisition utilising 4G and a centrally hosted visualisation app has never been achieved in composite manufacturing to date.

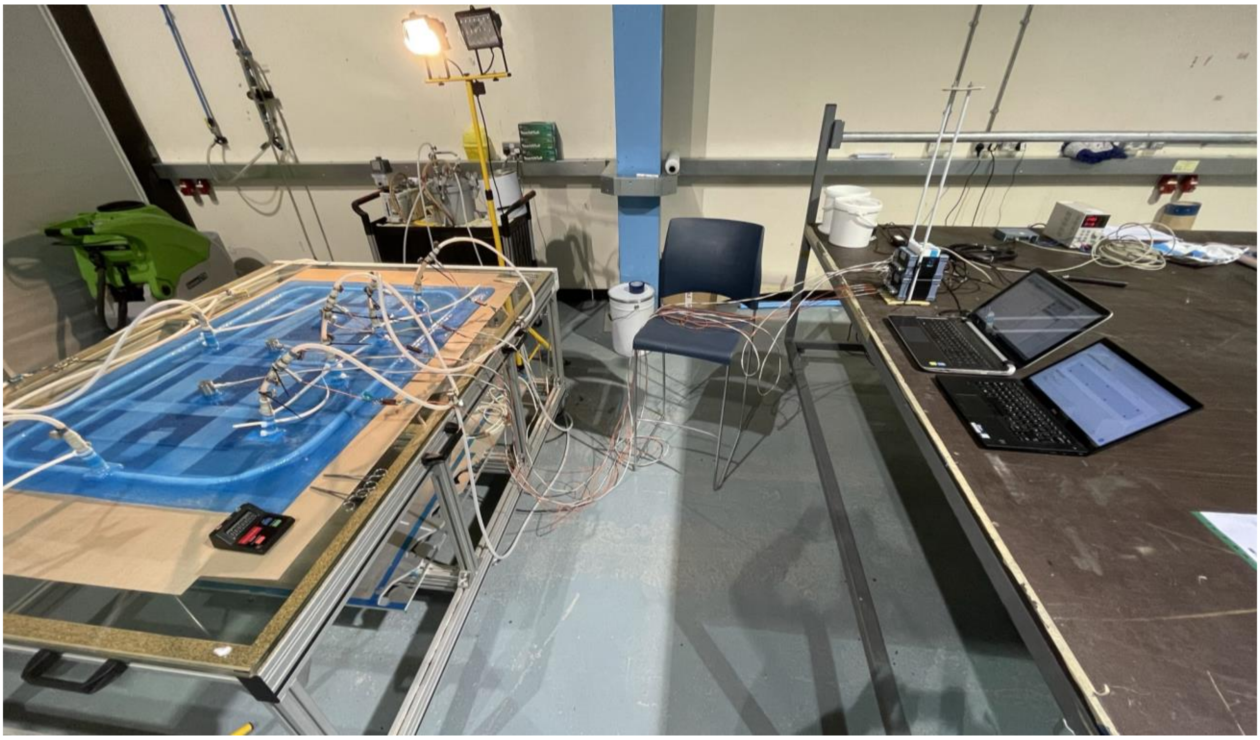

Figure 2 - Use case manufacture set up

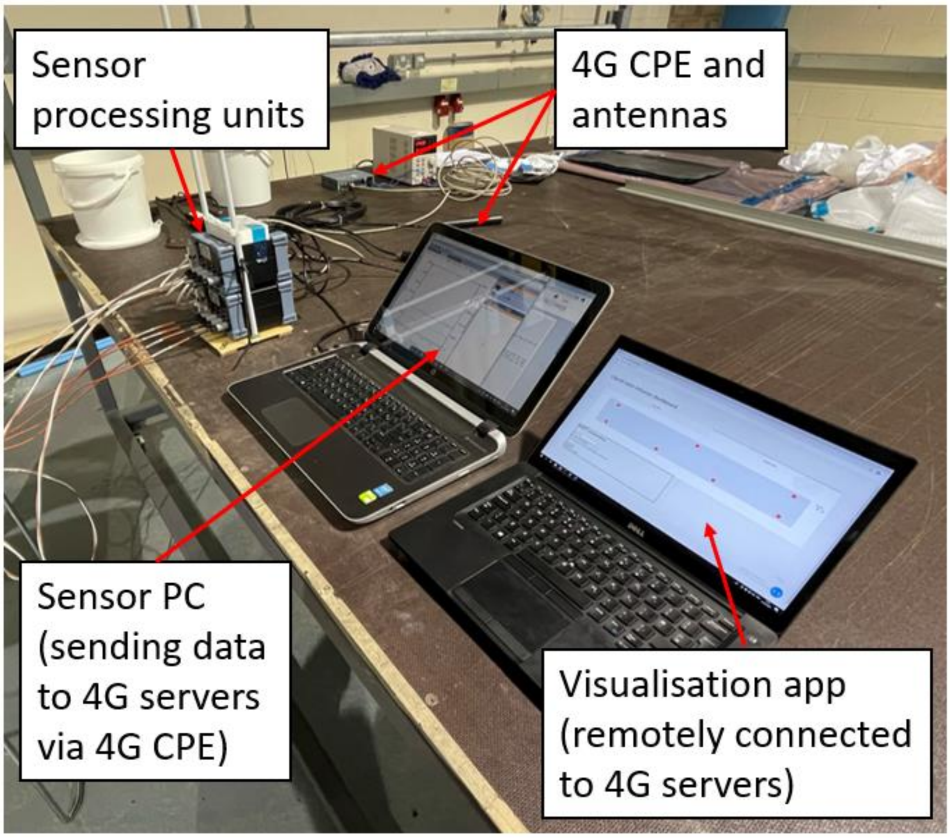

Figure 3 - 4G data acquisition set up, and laptop displaying the visualisation app

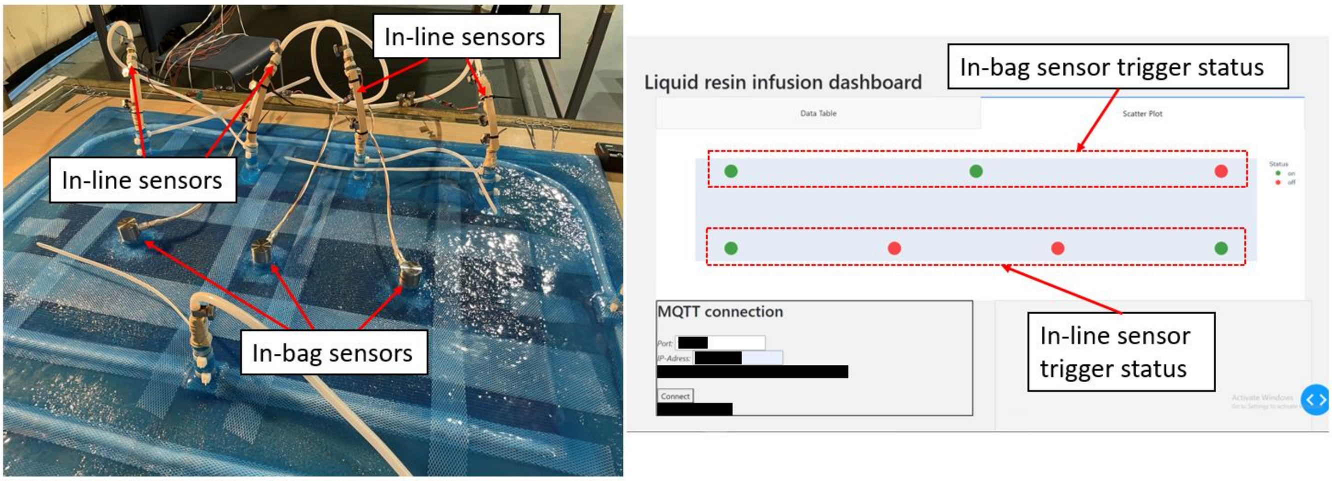

Figure 4 - Sensor arrangement on part (left), and view of the data visualisation app showing which sensors have been triggered (right)

Outcome, Results, and Industry Impact

The testing of the sensor system and visualisation system over the 4G network showed it to be working effectively - an operator can use the visualisation app to see what is happening in the process from anywhere. In this use case the part was made at room temperature (i.e. not in an oven) meaning the operator could visually see the resin flow, however for high performance composites, manufacturing must be done at high temperatures. This is where this sensor system would be hugely beneficial since it would be impossible to visually monitor the resin flow through the part when it is inside an oven.

Additionally, this work has validated the first phase of the architecture framework for utilising 4G (in future 5G) and digital technologies to monitor and visualise industrial manufacturing processes. This architecture is applicable to all types of manufacturing, not just composites.

This use case was demonstrated with 4G, using only 7 sensors in total (sending small quantities of data) and limited to how acquisition and visualisation can be performed. The benefits of 5G such as scalability and massive machine communication will be required if this system was, for example, deployed on the production of an aircraft wing, as hundreds of sensors sending data in unison would be needed. This vast number of required sensors would quickly overwhelm a 4G network.

Phase 2 will move to using 5G communication, giving insights into the specific challenges posed when implementing 5G in industrial manufacturing and will verify the system still works effectivity as is. Additionally, Phase 2 will introduce control systems that use the sensor data to automate manufacturing by enacting process changes without human input. This system will need the low latency achievable on 5G to make rapid process changes. The industrial benefits will be more fully realised when the next element of the Closed Loop LRI system is built in Phase 2; the breakdown of the system development is shown in Figure 5.

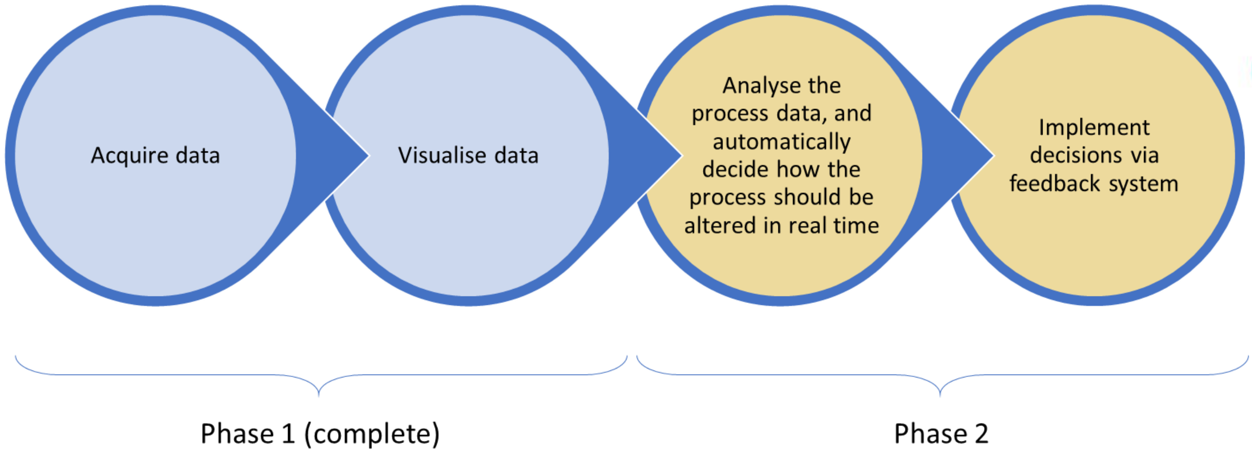

Figure 5 - Phase 1 and Phase 2 development description

Once complete, the Closed Loop LRI system will exploit benefits of 5G to begin enabling:

- Greater flexibility in the manufacturing set up
- Greater robustness
- System scalability
- Cleaner manufacturing spaces with fewer cables
- Higher safety

Finally, throughout the development of Phase 1 and Phase 2, best practices are being established on how to ensure robust deployment of 5G technology in industry, such as:

1. Where to host control models and visualisation systems
2. How to access these securely and reliably
3. How to ensure robust 5G communication between all the elements in an automated manufacture system (such as the sensor arrays, control systems, and the feedback systems)

These frameworks will be applicable to any manufacturing system (not just composites) ensuring the benefits of 5G can be leveraged across all the UKs advanced manufacturing sectors.

About 5G-ENCODE

The 5G-ENCODE Project is a £9Million collaborative project aiming to develop clear business cases and value propositions for 5G applications in the manufacturing industry. The project is partially funded by the Department for Digital, Culture, Media and Sport (DCMS), of the UK government as part of their 5G Testbeds and Trials programme. The project is one of the UK Government's biggest investment in 5G manufacturing to date.

The key objective of the 5G-ENCODE project is to demonstrate the value of 5G on industrial use cases within the composites manufacturing industry. It will also validate the premise that using private 5G networks in conjunction with new business models can deliver better efficiency, productivity, and a range of new services and opportunities that would help the UK lead the development of advanced manufacturing applications.

The project will play a key role in ensuring that the UK industry make the most of the 5G technology and ultimately remains a global leader in the development of complex composites structures using robust digital engineering capabilities.

The project will showcase how 5G features such as neutral hosting and network slicing can be applied to transform a private 5G network into a dynamically reconfigurable network able to support a wide range of applications (URLL/eMBB/MMTC) including industrial applications of Augmented Reality/Virtual Reality (AR/VR), asset tracking of time sensitive materials and automated industrial control though IoT monitoring and big data analytics. Such a dynamic network would enable new business models and creation of bespoke virtual networks tailored to specific applications or use cases.

The state-of-the-art testbed will be deployed across three sites centred around the National Composites Centre (NCC) in the South West of England. In support of the West of England Combined Authority (WECA) industrial strategy, the NCC plans to keep the testbed as an open access facility for the experimentation and development of new products and services for the composites industry after the completion of the 5G-ENCODE project. The location and nature of NCC's business would ensure the creation of an industrial 5G ecosystem involving multiple industry sectors and SMEs.

The project consortium brings together a Tier 1 operator (Telefonica), leading industrial players (e.g. Siemens, Toshiba, Solvay), disruptive technology SMEs covering all aspects of network design, deployment and applications (Zeetta Networks, Mativision, Plataine), a world-leading 5G network research group (High Performance Networks Group in the University of Bristol) and the NCC representing the high value manufacturing industry.

For more information about 5G-ENCODE, visit; https://www.5g-encode.com/ or email info@5g-encode.com