production

# Manufacturing large aerospace composite structures using liquid resin infusion

**As the world's aerospace industry looks to implement the serial production of composite wing structures into future production lines, there has been a noticeable shift in the approach to manufacturing large composite structures within the industry.**

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Traditionally, primary aerospace structures employing composite materials are manufactured using prepreg materials and autoclave curing to achieve components with the high fibre volume fraction/low void fraction required by stringent aerospace quality standards.

## OoA processing technologies

As the production rates of aircraft are set to increase over the next 5-10 years, some of the world's leading Tier One and OEM aerospace manufacturers have looked to out-of-autoclave (OoA) processing technologies to help drive down capital and processing costs while reducing production cycle times.

Over the last four years, Composite Integration has worked with a number of different partners on a series of collaborative R&D projects to identify processing areas that require development and optimisation, with an overall aim of fundamentally proving that OoA processes such as Resin Transfer Moulding (RTM) and Liquid Resin Infusion (LRI) can be used to produce high-quality composite components with fibre volumes and void fractions comparable to those of a prepreg and autoclave-cured equivalent.

Through research and development work carried out by Composite Integration in collaboration with Safran Aircelle and the University of Nottingham, under the Propound AMSCI-funded project, it was determined that LRI is an entirely viable process for manufacturing primary aerospace structures.

## Process map

One of the critical outcomes from the two-year project is a "process map" that defines a series of steps that should be followed and "gates" that need to be passed through in order to significantly reduce the risk of process failure (Figure 1).

An element identified as being critical to successful infusion was the ability to finely control and monitor the injection parameters throughout the duration of the process. A high level of process control and, in particular, intelligent regulation of the resin inlet pressures (and therefore fibre compaction) allowed high-quality components to be manufactured.

In order to facilitate the process repeatability, a range of machinery was developed specifically for processing high-temperature epoxy resins in a lab/small-scale production environment. Composite Integration's Ciject 3™ range of equipment utilises a pressure vessel-based injection system combined with PID-controlled pressure regulation. The use of high-resolution industrial pressure transducers at the infusion inlet allows direct feedback to the pressure vessel, which in turn allows the machine to dynamically regulate the flow of resin into the mould. This is especially critical for multi-inlet infusion strategies where the vacuum conditions inside the bag change rapidly as new feed lines are opened.

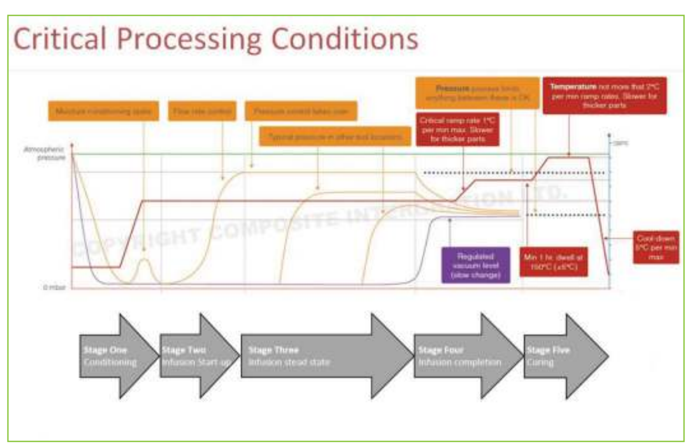


Fig. 1: Critical processing conditions


Fig. 2: Large Scale Resin Infusion (LSRI) equipment capable of injecting up to 400 kg of resin

As aerospace manufacturers start to move through the Technology Readiness Levels (TRL), there is now a requirement to scale up the whole infusion process to demonstrate the lessons learned at the demonstrator scale on a full-scale component.

### LSRI equipment

Composite Integration was commissioned by the National Composites Centre (NCC) in Bristol, UK, to develop and supply equipment capable of injecting up to 400 kg of either single- or two-component aerospace-grade epoxy resin systems, under the iCAP programme, a £36.7m investment in ten digital manufacturing technologies at the NCC.

The acquisition of the Large Scale Resin Infusion (LSRI) equipment (Figure 2) enables the NCC to widen the applicability of LCM processes to a wider range of components. The first application of the technology will enable the infusion of complete wing components as part of next-generation wing technology developments.

### Integrated heating system and vacuum pump

This ground-breaking equipment uses two process tanks to store and condition the resin and hardener systems. An integrated heating system and vacuum pump allows for full degassing and heating of the materials prior to injection. A modular pumping system allows processing of both single- or two-component resin systems. In the single-pump configuration, flow rates up to 4 litres/minute are achievable. When the pump modules are changed to allow two-component pumping, the maximum flow rate increases to 20 litres/minute.

In both configurations, a PID-controlled pressure feedback loop facilitates accurate regulation of resin into the mould. The use of precision flowmeters allows flow rates and process volumes to be monitored and controlled throughout the duration of the infusion.
Looking to the future, as Industry 4.0 continues to gain traction and become reality over the next 5-7 years, there will undoubtedly be a need for infusion processing to become fully automated.

### Centralised control and full integration

In a "traditional" infusion process, the operator has to select which feed lines to open at a specific time throughout the duration of the infusion. Although manual control systems can be implemented, this decision-making process is largely subjective.

As the scale, complexity and costs associated with aerospace infusion start to increase, component failure due to subjective decision-making during an infusion is simply not an option.
In order to address this issue, alongside the work completed in conjunction with the NCC, Composite Integration also developed and patented a novel system for distributing resin to multiple infusion inlets.

Resin is fed through suitably heated and pressure rated pipework to a modular manifold station. Each manifold port can be opened and closed via a remote connection to the injection machinery. Once the injection is com-

**Focus**

**Composite Integration Ltd.**
Composite Integration Ltd. provides market-leading solutions to the composites industry, specializing in resin transfer moulding and resin infusion processes. Founded on a background of practical experience and targeted development, the company offers a full range of RTM and infusion machinery, as well as ancillary equipment and materials, supported by comprehensive tooling and training services.

**Focus**

**NCC**
The National Composites Centre (NCC) offers open access to cutting-edge digital manufacturing technologies, helping companies across the UK to accelerate the design, development and scale-up of new composite products and processes.
Over 350 specialist composites engineers based at its Bristol facility work with industry and universities to foster the adoption of high-value, sustainable engineering solutions based on composites, pulling through technology from the lab to large-scale production.

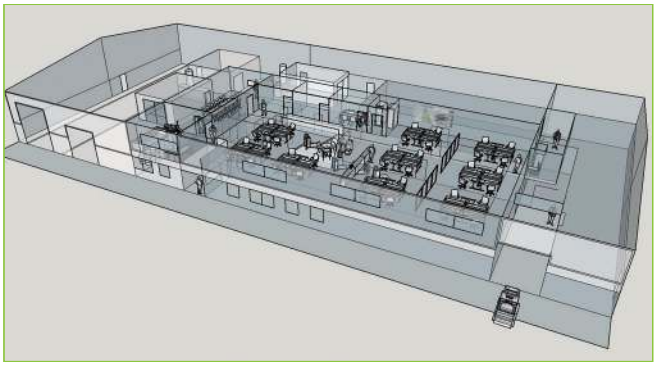

Fig. 3: Composite Integration's latest investment to support its development

pleted, the manifold can be automatically flushed, ready for use in the next injection cycle. All the actions carried out by the operator at the injection machine interface are logged on a data acquisition system.

This approach allows centralised control and full integration of the infusion process. This in turn improves the consistency and repeatability of the process.

### Intelligent control without operator input

The next developmental stages of this project are to take the integrated infusion system (injection machinery and manifold system) and combine it with additional in-mould instrumentation to provide real-time feedback as to how an infusion is progressing. When combined with appropriate SCADA systems, the aim is, for the system as a whole, to be able to intelligently control the infusion without input from an operator.

As machinery size increases, so too does the space required to build them. As a direct result of the work carried out with the European aerospace industry over the last four years, combined with ongoing work within the renewable energy sector, Composite Integration is experiencing a period of accelerated growth, and recently completed the purchase of new, larger premises in Saltash, UK (Figure 3).

The 1500m$^2$ facility will allow for further business expansion over the next ten years and is currently undergoing a comprehensive refit to make it suitable for manufacturing high-quality, large-scale equipment for use in the composites industry. ◻

**More information:**
**www.composite-integration.co.uk**
**www.nccuk.com**