TURBO newsletter Jan-2024 (#2)

TURBO

Towards turbine blade production with zero waste

For more info visit the website https://turboproject.eu
Or join the **NEW** LinkedIn group: https://www.linkedin.com/company/turbo-project

Welcome to the second TURBO project newsletter!

In this edition we provide some updates on several areas of project activity, and other project news:

- TURBO booth at AMI Wind Turbine Blades event (Dec-2023)
- ESI progress on infusion process monitoring and simulation
- An overview of ARDITEC work on sustainability assessment
- Initial results on wireless monitoring development at CPI

Finally, don't forget to join the NEW LinkedIn group: see above!

TURBO at AMI Wind Turbine Blades (Düsseldorf; 12-14 Dec-2023)

AMI | Events
Wind Turbine Blades
12-14 December 2023 | Düsseldorf, Germany

Following a very successful event last year, TURBO had a tabletop booth (Booth #5) at the AMI Wind Turbine Blades conference and exhibition at Düsseldorf Maritim Hotel (image right). Conveniently located near the airport, the conference ran from 12-14 Dec-2023 and is a well-established industry event which includes industrial experts as well as executives and academics in the field. Several TURBO representatives attended and, in addition to a full and highly relevant conference agenda, there was a small exhibition area which was an excellent place to meet interested parties for questions and discussion.

Consortium

DTU · SIEMENS Gamesa RENEWABLE ENERGY · NORBLIS Nordic Broadband Light Solutions · HÜBERS · NATIONAL COMPOSITES CENTRE · synthesites · ARDITEC · UNIVERSITAT POLITÈCNICA DE VALÈNCIA · SMARTIA · esi get it right · cpi · VIVID COMPONENTS

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Funded by the European Union

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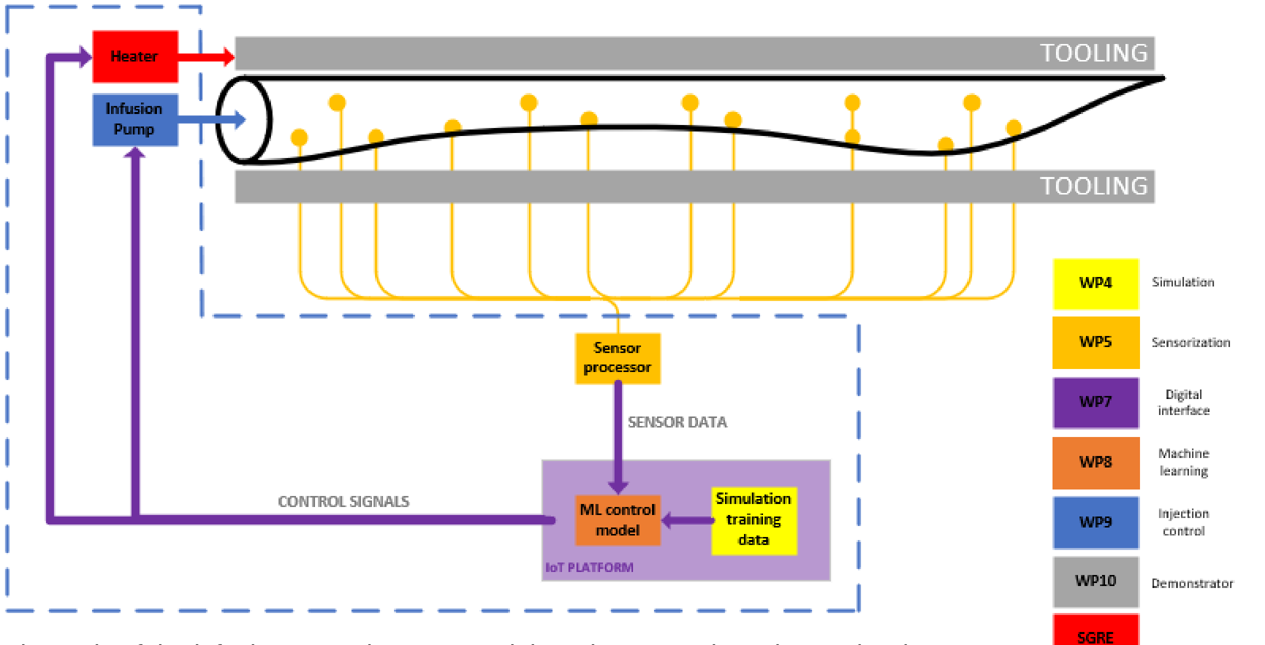
Infusion process monitoring and simulation

SIEMENS Gamesa RENEWABLE ENERGY
esi get it right

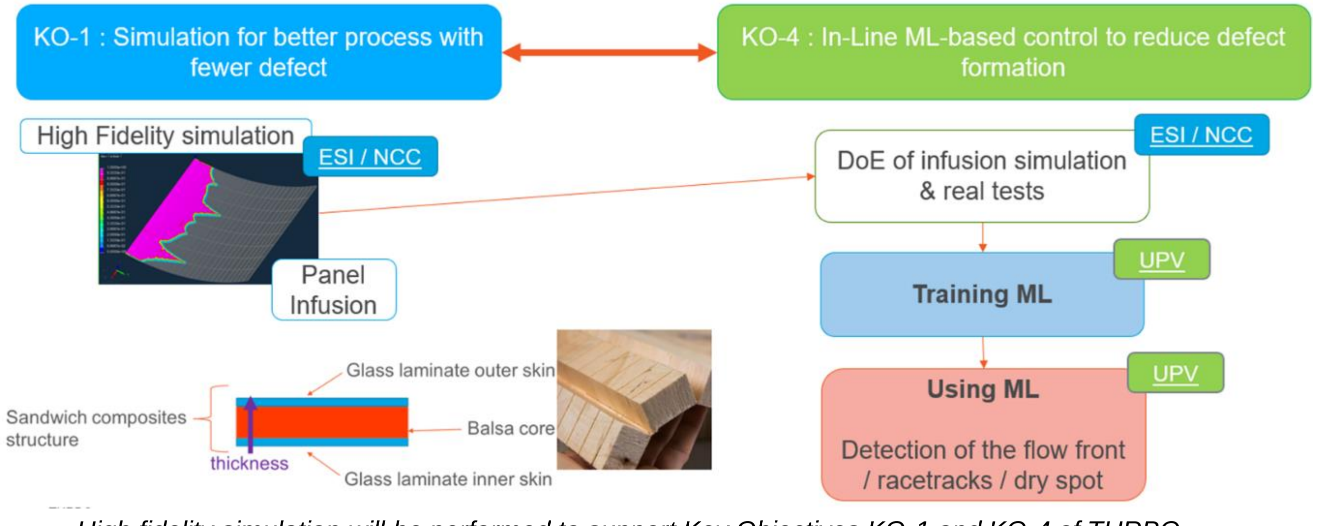


Schematic of the infusion control system and the relevant work packages (WP).

A key objective of the TURBO project is to improve the digitalisation of the manufacturing process of wind turbine blades at Siemens Gamesa Renewable Energy (SGRE), with an Industry 4.0 approach as a long-term target. In this context, a first goal is the smart monitoring and control of the infusion process to fabricate the wind turbine blade, followed by smart inspection processes using non-destructive testing. To support these objectives, different simulation tools are being developed: virtual permeability characterisation, infusion simulation, curing simulation, curing-induced wrinkle formation simulation, wrinkle defect severity evaluation, *etc*.

These simulation tools have different purposes:

- Virtual material characterisation to standardise the use of infusion simulation, where obtaining the correct material inputs is often an obstacle (due to cost or availability).
- Simulation for better process understanding.

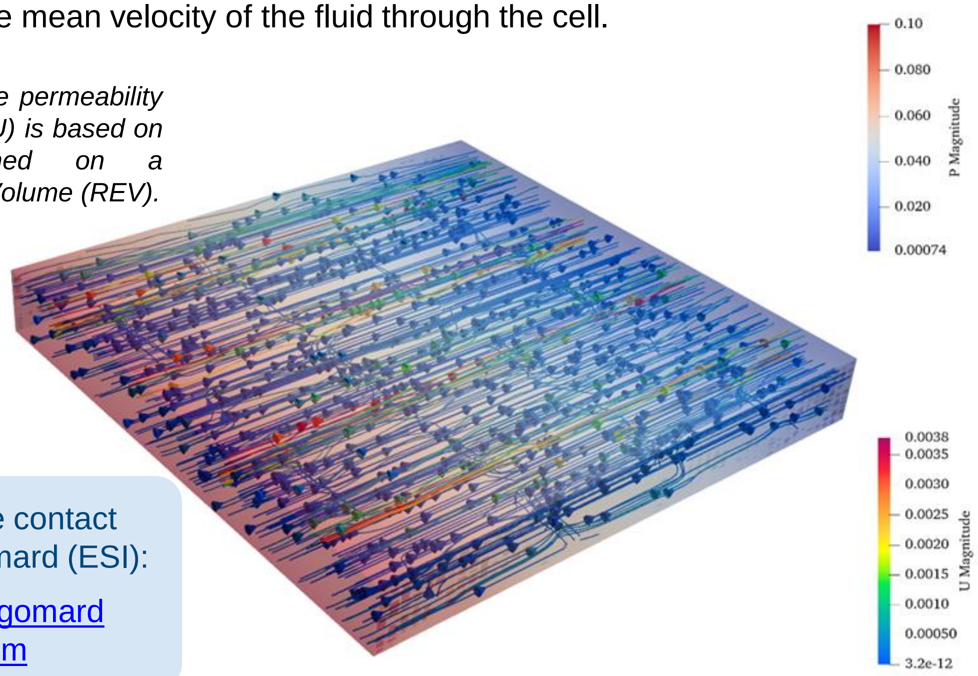


High fidelity simulation will be performed to support Key Objectives KO-1 and KO-4 of TURBO.

- Support the creation of the machine learning (ML) work to be performed by UPV, by providing synthetic data before the real experimental data is available.

The virtual characterisation of the permeability for infusion process (performed by DTU) is based on fluid simulation performed on a Representative Elementary Volume (REV) of the considered material (single fabric or laminate); an example is shown below. From these simulations, the permeability can be assessed by relating the applied pressure gradient boundary conditions to the mean velocity of the fluid through the cell.

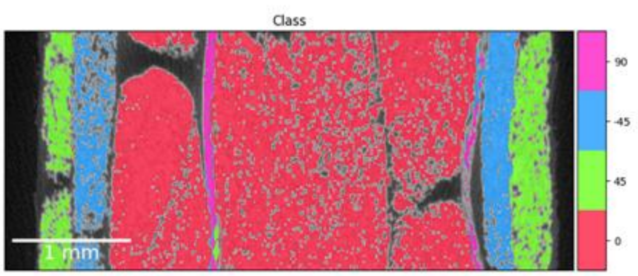
Virtual characterisation of the permeability for the infusion process (DTU) is based on fluid simulation performed on a Representative Elementary Volume (REV).



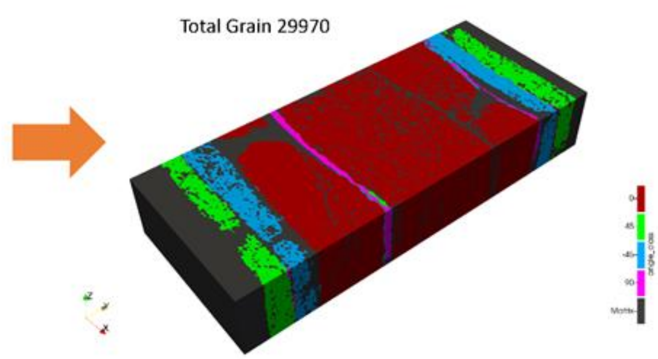
For more info, please contact Yann Duplessis Kergomard (ESI):

Yann.DuplessisKergomard@esi-group.com

One of the main difficulties for the virtual characterisation of the permeability is to achieve a sufficiently realistic geometric representation of the REV. To address this challenge, DTU is currently constructing a methodology to create a mesh from tomography scans, as shown below. An important aspect is the thickness of the fabric, which evolves during the infusion process with the pressure evolution; the methodology will be improved to include this effect.



Single slice of an NCF composite on XY-plane (using Python script)



Creation of mesh for the REV cell obtained from tomography scan.

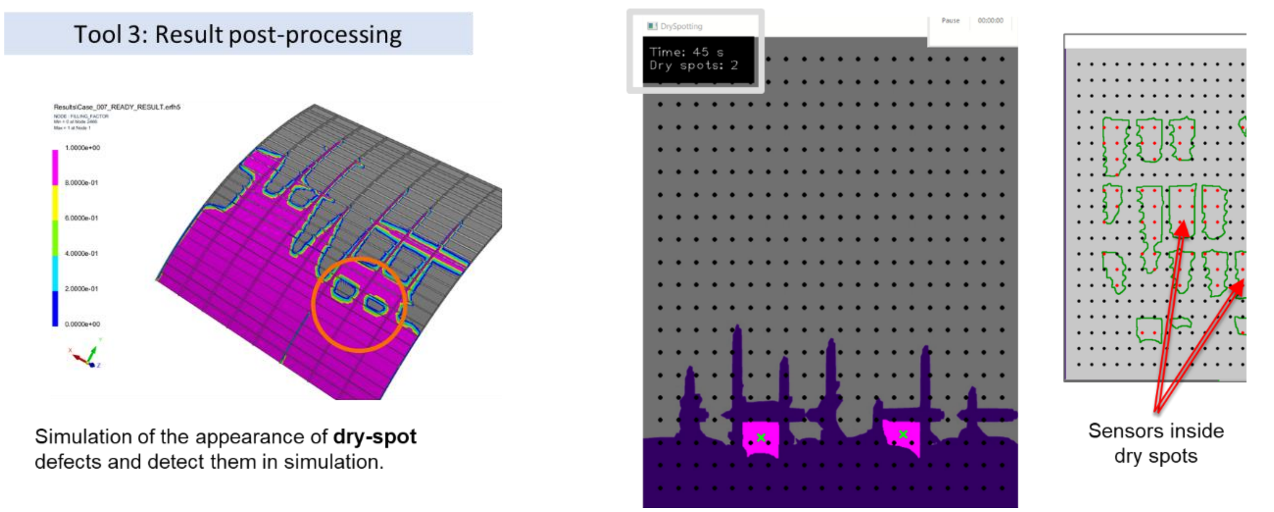
Constructed mesh image of 100 slices across Z-axis (in ParaView)

In parallel, the simulation of the global infusion process is being considered by NCC and ESI, with the final target to precisely simulate a whole section of the blade for the final demonstrator. The simulations are performed with ESI's PAM-COMPOSITES™ solution. The first objective is to get a better understanding of the physics and phenomena involved, especially the occurrence of manufacturing defects such as dry spots. These simulations will

Funded by the European Union

support the conception of the real trials to be tested. However, before simulating the final demonstrator, several intermediate trials with increasing complexity will be considered. The first, which has already been modelled, is a curved panel of 3×3 m^2, including important details of the composite blade sandwich structure, especially the balsa core. This core is made of several smaller panels with grooves, V-cuts and variable gaps between balsa panels. All these features, modelled in the virtual trial shown below, have a major impact on the local permeability and the resin path. For instance, the gaps between balsa panels could create resin race-trackings which in turn could lead to dry-spots in some conditions.

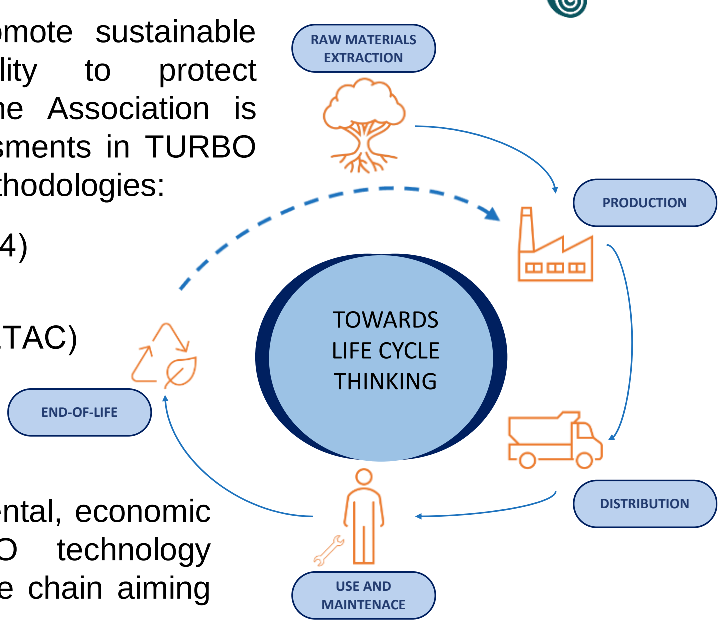
Another main objective during the project is to support the machine learning development at UPV by feeding data for the training of the models. Hundreds of simulations have been performed with various boundary conditions at the inlets, different balsa panel configurations and various inter-panel gaps. The virtual defects are located and the corresponding signals from the virtual sensors are simulated and used to feed the ML models.



Infusion simulation done with PAM-RTM™ on a curved panel, representative of the sandwich structure of a wind turbine blade. The results of the simulation are used to detect the possible formation of dry spot zones by image analysis. The information located at the virtual sensors is sent to UPV to enable the training stage of machine learning models.

Sustainability assessment work in TURBO

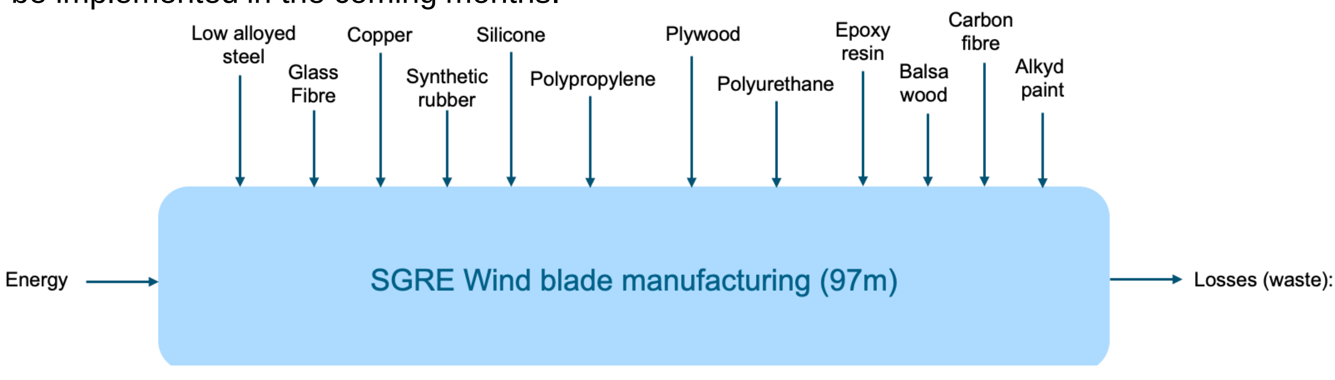
The ARDITEC Association aims to promote sustainable development and social responsibility to protect environmental and cultural heritage. The Association is currently leading the sustainability assessments in TURBO by using several relevant standardised methodologies:



- Life Cycle Assessment (ISO 14040/14044)
- Life Cycle Costing (ISO, 2006)
- Social Life Cycle Assessment (UNEP/SETAC)
- Material Circularity Indicator (MCI) methodology (developed by the Ellen MacArthur Foundation).

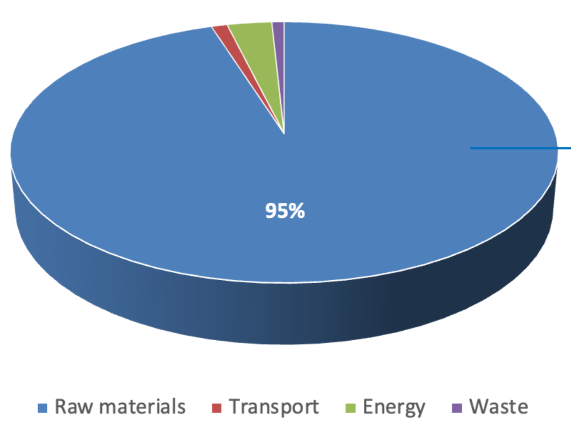
The objective is to quantify the environmental, economic and social benefits of the TURBO technology implementation in the current SGRE value chain aiming to produce wind turbine blades of various sizes and designs, whilst minimising both waste and energy consumption. An initial assessment is being conducted on the current production chain in order to quantify the sustainable benefits later in the project.

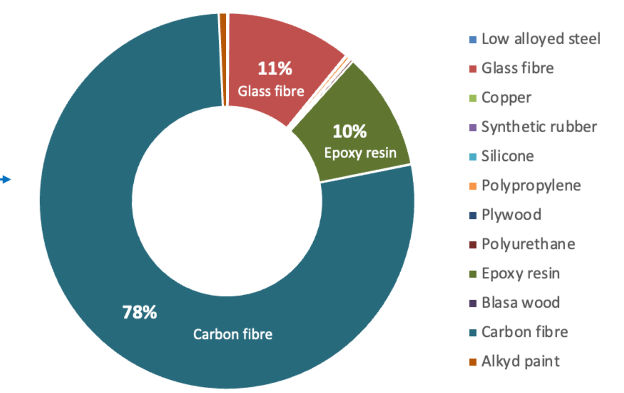
In TURBO, ARDITEC has been focusing on the scope of the study and the assessment of the baseline scenario which will be used as the reference to quantify the potential environmental benefits of the technologies (*i.e.* non-destructive testing, machine learning, digital twin *etc*.). Working with the teams at SGRE and NCC, ARDITEC has defined the approach which will be used to conduct the different assessments (system definition, scope, functional unit, impact categories *etc.*). Following an initial evaluation using secondary data from literature, primary data collection has started for a 97 m blade from SGRE's current production (see below), and each dataset has been refined during this first period through an iterative process (including energy, water and material resources, emissions and waste). This preliminary work has identified the hotspots in the current value chain, and the results will be compared to the calculations related to the demonstrator where the technologies will be implemented in the coming months.



Key elements of wind turbine blade manufacturing in the current Siemens Gamesa Renewable Energy production chain used in the sustainability assessments.

Using the software Simapro 9.5.0.0 and the impact assessment method Environmental Footprint 3.0 Method (adapted), ARDITEC calculated the environmental impact related to the baseline scenario. Several figures were presented to SGRE, including the distribution of impacts, normalised values with a single score and the most impactful categories. The results were also broken down per input category, highlighting the highest contributors in each impact category, such as kg CO_2 eq, resource use (fossil-based) in MJ, and other resource use (minerals/metal) in kg Sb eq as shown below.





Result breakdown per inputs category.

Current status and next steps

All the results will be further refined in Q1 2024 along with the datasets communicated by SGRE and compiled in the public deliverable D11.1-Preliminary report of environmental LCA, LCC and S-LCA (Mar-2023). In parallel, Life Cycle Costing and Social Life Cycle Assessment (S-LCA) studies have also started as they share the same system definition and approach. ARDITEC is evaluating the economic impacts and production costs, initially using external sources, to analyse capital and operational expenditures and financial ratios of the current production chain.

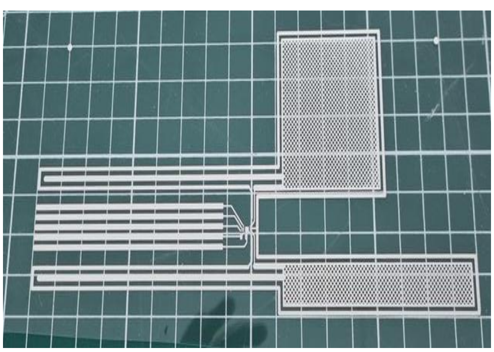
Planned activities later in the project

To enhance the screening LCA, more accurate datasets will be incorporated, particularly regarding waste and energy. Additionally, all inventory data related to the environmental assessment will be translated into economic values to facilitate the LCC analysis for the current value chain. In terms of S-LCA, ARDITEC will begin classifying stakeholders based on their power and interest and will start preparing the interviews with each partner. Finally, once the results for the environmental evaluation of the baseline scenario are available, ARDITEC will propose various circular pathways to integrate the Material Circularity Indicator and maximise resource circularity.

For more info, please contact José Gallego jose.gallego@arditec.net

Wireless monitoring development at CPI

As part of the TURBO project, in collaboration with several other partners, CPI is developing an embedded wireless sensing system fabricated on flexible substrate that will measure resin arrival and temperature and will wirelessly send data from inside the mould using LoRaWAN® (Long Range Wide Area Network).



Printed capacitive sensor.

CPI investigated the compatibility of inks used in capacitive resin flows with epoxy resins used for WTB manufacturing. While the inks showed no adverse effects, the study revealed that if sensors come into direct contact with curing epoxy resin, they may adhere destructively, potentially causing defects. Recommendations include assessing resin leakage risks, further testing on designed sensors and exploring encapsulation options to prevent sensor-resin contact during cure.

CPI has now verified the capacity of the sensors to detect resin flow, selected the primary components for the sensor label, and completed the design of the sensor label test board, including the schematic and PCB. Results to date are very encouraging and the next step of integrating this sensor system into production equipment is on schedule.

Printed capacitive sensors detect flow through cores in lab trials. The arrow shows where resin has flowed to the end of the panel through grooves well before the top surface was saturated.

For more info, please contact Adrian.Wong@uk-cpi.com