

Towards turbine blade production with zero waste

Welcome to the sixth TURBO project newsletter!

This edition contains updates on the following topics:

- TURBO NDT demo at Siemens Gamesa
- Smarter infusion control for WTBs with reinforcement learning from UPV
- Arditec assesses the sustainability impact of process optimisation in WTB manufacturing
- Norblis sets new state-of-the-art in mid-IR optical coherence tomography (OCT)
- Multi-objective optimisation of textile preform architectures from DTU Construct.

For more info visit the website:

<https://turboproject.eu>

Please join the TURBO LinkedIn group!

<https://www.linkedin.com/company/turbo-project>



NDT demo at Siemens Gamesa

In Mar-2026, the TURBO consortium gathered at the Siemens Gamesa Renewable Energy facility in Aalborg (Denmark). A key part of the agenda was to see the two TURBO NDT systems in action: both mid-IR OCT and thermography. The results were very impressive, and the mid-IR OCT system from Norblis defines a new state-of-the-art. More info on these tests will be published in the coming period so please keep following the TURBO LinkedIn group!



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This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101058054 (TURBO). This includes funds from UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee [grant numbers 10037822, 10042318 and 10044756] as part of the topic ID HORIZON-CL4-2021-TWIN-TRANSITION-01-02.

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Smarter infusion control for wind turbine blades with reinforcement learning

Producing large wind turbine blades through resin infusion is a demanding process. Flow instabilities, permeability variations or small asymmetries can easily lead to defects such as dry spots or incomplete impregnation. Within the **TURBO project**, UPV is investigating how **reinforcement learning (RL)** can help to control the infusion process actively and improve robustness in realistic manufacturing conditions.

Learning to synchronise resin flow

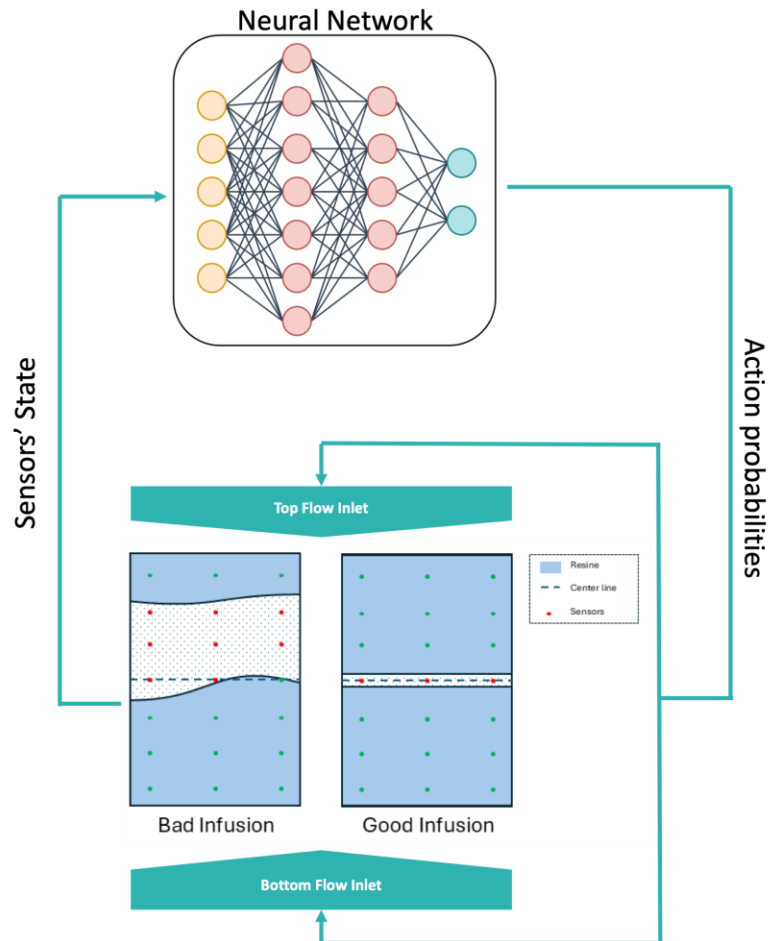
The work focuses on a **dual-gate resin infusion system** in which resin enters the mould from opposite sides. If one side of the resin flow reaches the vent before the other, it blocks the vent, removes the pressure gradient and prevents further infusion, effectively “freezing” the process. The objective is to **synchronise both resin fronts** so that they reach the central vent at the same time, even when the material presents heterogeneous permeability or racetracks.

To study this problem, we use a **2D vertical infusion simulation** with top and bottom inlets. The system is deliberately made asymmetric to reflect real manufacturing conditions. Instead of having full access to the flow state, the RL agent relies on **binary sensors** distributed across the mould to indicate whether resin has reached specific locations, just as in the real TURBO process.

Reward design and results

Based on this partial information, the agent automatically selects one of the control actions related to inlet activation. The agent is trained with a reward function that promotes **balanced and synchronised flow propagation**. It rewards the simultaneous activation of symmetrical sensor rows and penalises deviations of the resin centroid from the vent line, as well as unnecessarily slow fillings.

The results show that the learned policy can adapt inlet control to compensate for flow asymmetries, achieving synchronised arrival of both resin fronts at the vent in situations where simple control strategies fail.



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Assessing the sustainability impact of process optimisation in wind blade manufacturing



As the sustainability partner in the TURBO project, ARDITEC is currently evaluating the environmental benefits of the TURBO technology developments.

As an intermediate step, the analysis focuses on a comparison between a baseline casting process and an improved infusion strategy, based on process optimisations such as inlet positioning and infusion parameters. This approach represents a key step toward the full deployment of TURBO solutions.

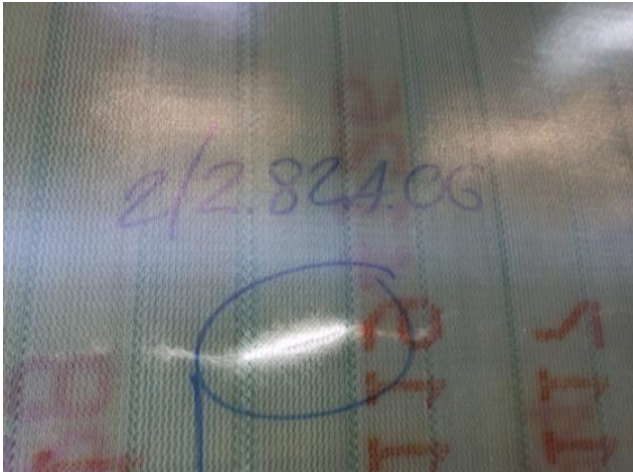
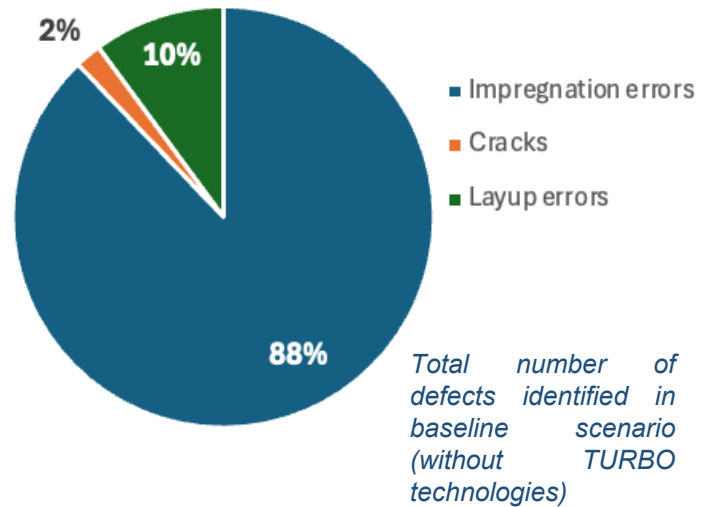


Photo of a typical defect.

First comparative results:

- Total number of defects
 - Baseline (Casting 1) 56
 - Improved strategy (Casting 2) 39
- Defect reduction: 30 %

Even at this stage, the defect reduction leads to significant benefits:

- Fewer man-hours required for repair
- Lower consumption of repair materials
- Improved environmental performance of the manufacturing process.

These initial results highlight how process optimisation alone can already deliver measurable sustainability benefits, paving the way for even greater impact as TURBO technologies continue to mature.

These results highlight the potential of **reinforcement learning as a control tool for resin infusion processes** relevant to wind turbine blade manufacturing. By learning from interaction rather than relying on fixed rules, RL-based controllers can adapt to uncertainty and variability, paving the way for more reliable and efficient composite manufacturing within the TURBO project and in manufacturing in general.

These latest advances were presented at the 45th Risø International Symposium on Materials Science, highlighting the growing potential of AI-driven process control in composite manufacturing.

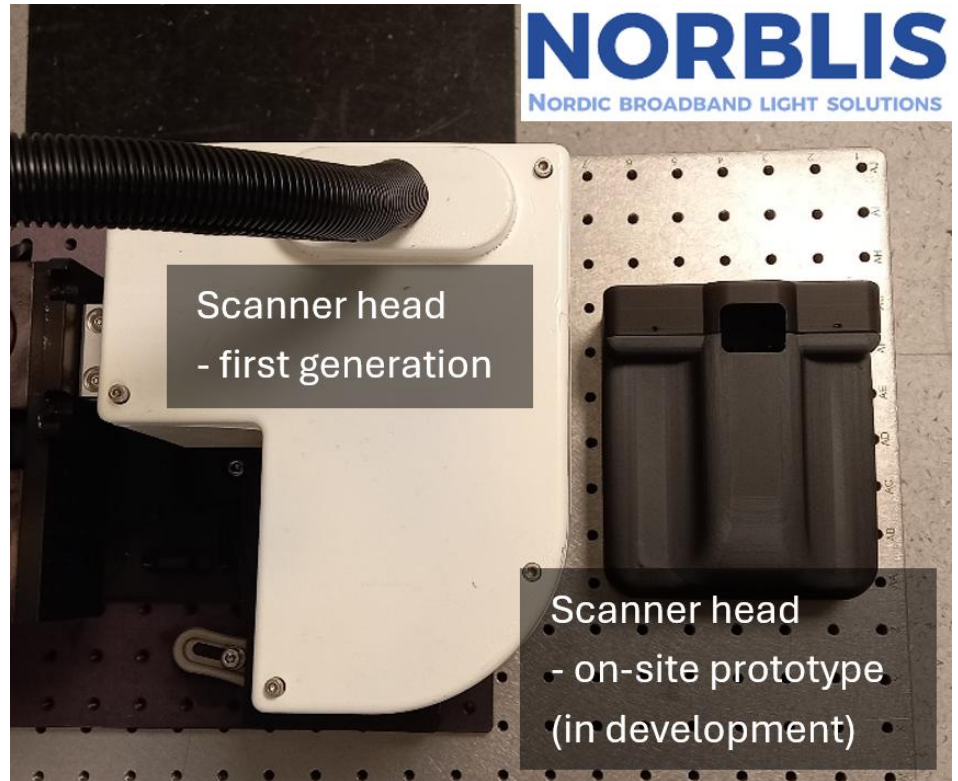
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Norblis sets new state-of-the-art in MIR OCT

Development of the world's first scanner for sub-surface mapping of wind turbine blade coating quality:

Exploiting deep penetration MIR OCT (mid-infrared optical coherence tomography).

The TURBO project team prepared the on-site demonstrations for the imaging of blades from Siemens Gamesa Renewable Energy in Aalborg, Denmark (see cover page). These modern blades are longer than 100 m and consist of asymmetric curved surfaces. For this reason, advancing traditional OCT imaging processes from millimetre to metre scale scans, and from imaging simple plane surfaces to complex curved objects is essential. In doing so, project partner NORBLIS is modifying its world-leading first generation MIR OCT scanner, Mirage, to make it suitable for the blade production environment. A central element is the scanner head where an on-site prototype is in development to be combined with Siemens Gamesa blade scanning infrastructure.



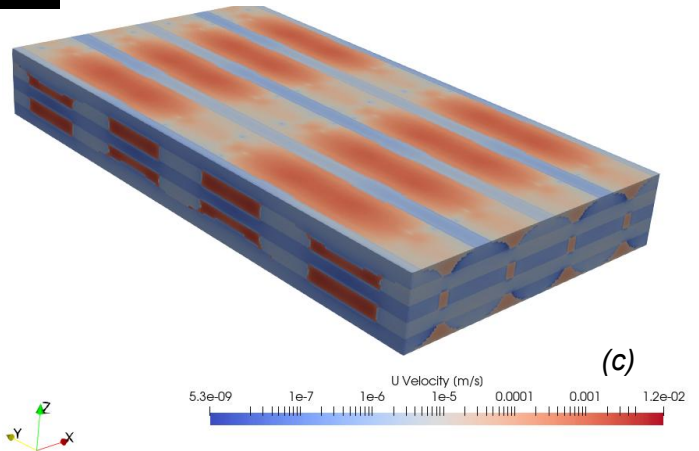
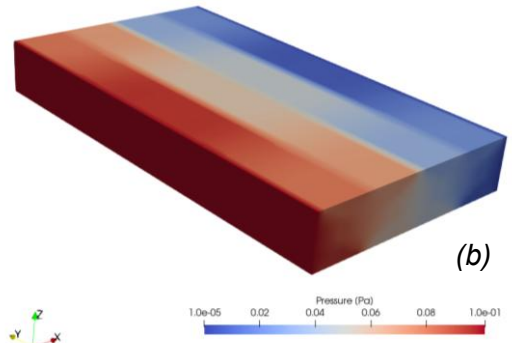
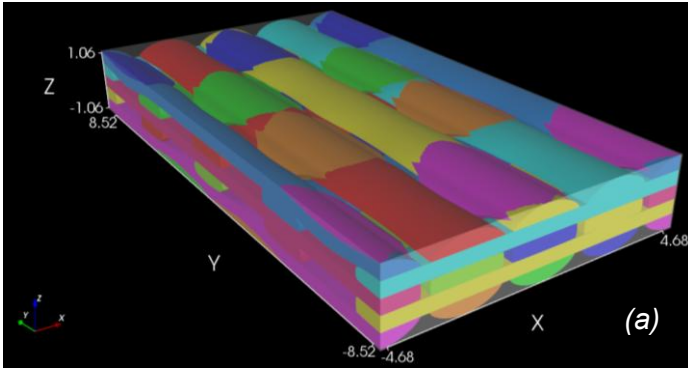
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Multi-objective optimisation of textile preform architectures



The TURBO simulation team at DTU Construct carried out a multi-objective optimisation of textile preform architecture by varying the yarn geometry and key design parameters: warp and weft spacing, number of layers, weave/pattern and binder distribution, to identify configurations that simultaneously increase the principal permeability components (K_1 , K_2 and K_3) while maintaining a high fibre volume fraction (V_f). The optimisation framework was implemented in Python using the *non-dominated sorting genetic algorithm II* (NSGA-II).

For each preform design, the geometry was generated in TexGen and then converted into an OpenFOAM-compatible mesh. The model includes dual-scale porosity by treating the yarns as porous media with assigned directional, yarn-level (micro-scale) permeability. Meso-scale flow simulations were then performed to compute the effective (global) permeability for flow both parallel and transverse to the warp/weft directions.

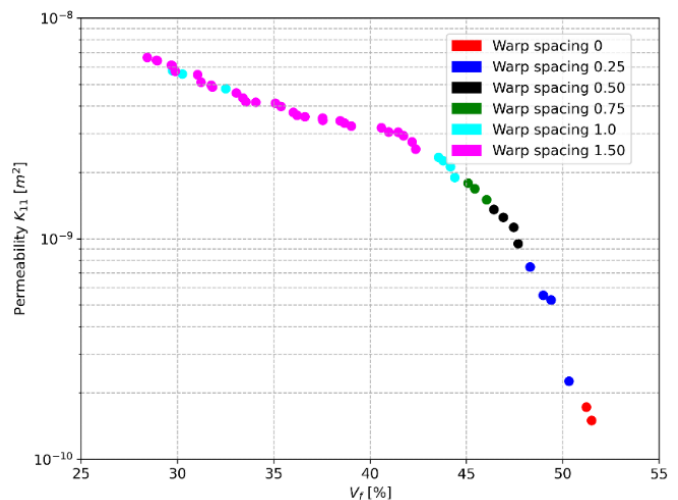
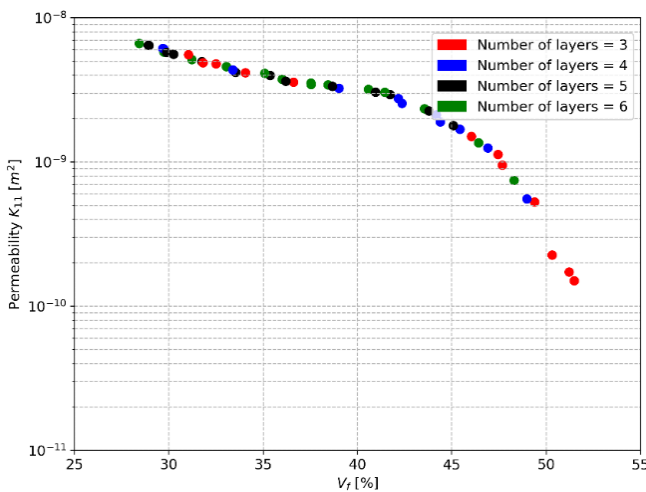


An example idealised preform:

(a) A representative geometry comprising 2–3 warp and weft layers with a binder acting as stitching between layers, and the corresponding dual-scale flow results for

(b) Pressure and, (c) Velocity.

The predicted pressure and velocity profiles within an example idealised preform are shown here. A representative pareto-optimal front after 15 generations is presented in the graphs below, illustrating trade-offs when varying the number of layers, warp spacing while maximising K_1 and V_f .



A representative optimal design after generation 15 is shown for (left) number of layers and (right) warp spacing.

The full optimisation study is ongoing, with the aim of proposing pareto-optimal preform designs under a true multi-objective formulation using higher-dimensional optimality criteria.

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