

**TITLE:** Flow Control for the Resin Transfer Moulding (RTM) Process based on MATLAB forecasting

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**ABSTRACT:** Resin Transfer Moulding (RTM) is a well-established manufacturing method due to its ability to produce high-quality fibre-reinforced components. It is increasingly used for the manufacture of aerospace composite structures as it reduces material waste and cost compared to Autoclave moulding, which is the main method of manufacturing for large composite aerostructures. However, process control remains a major barrier to achieving consistent product quality in terms of uniform impregnation, low void content, and reproducible mechanical performance. Implementing a robust resin flow control strategy is therefore necessary to improve process repeatability and quality assurance for large RTM processes.

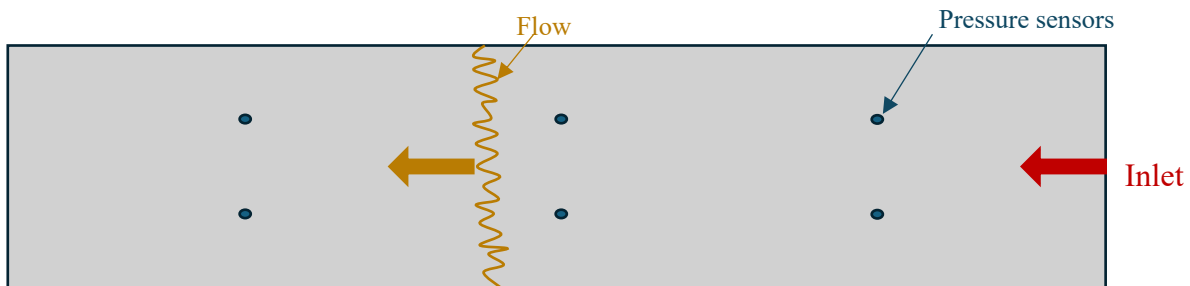
In industrial RTM, process control is often rudimentary, and resin flow front advancement is often uncontrolled, which may lead to non-uniform filling, dry spot formation, and premature gelation. These issues are caused by variations in local permeability. As a result, the final composite quality is highly dependent on operator experience, mould set up, and other systems that can be put in place to ensure a high-quality part can be produced, limiting process efficiency and scalability for aerospace applications. Problems can be caused by:

1. Uncertainty in local fibre volume fraction and local permeability across the fibre preform.
2. Limited information of exact flow front shape or location during the process
3. Reactive control strategies that respond after defect formation has not been tested extensively for larger moulds
4. Complex coupled physics (flow, heat, cure) that make model-based control difficult to implement directly.

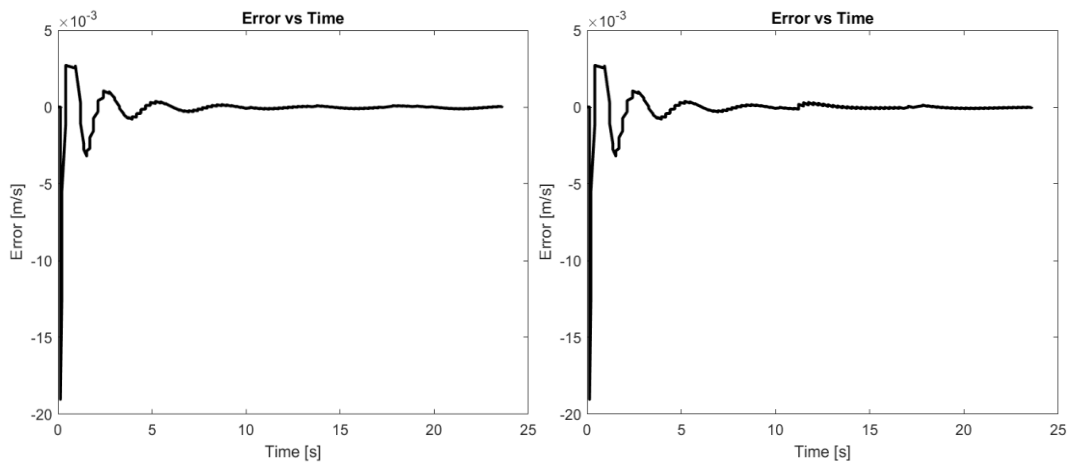
This work proposes a pressure-sensor-based feedback control system integrated with a Darcy-flow simulation of the RTM process. The approach involves:

- Using inlet pressure as the control variable to regulate resin advancement through the preform.
- Developing a numerical forecasting model that predicts flow front position using real-time pressure feedback (Currently using 1D MATLAB estimation with various simplifications to the model)
- Implementing a PID or gain-scheduled control algorithm in MATLAB/Simulink and in injection experiment to dynamically adjust the inlet pressure to work towards a specific control objective (i.e. target fill time, constant pressure, etc). The control design aims to control the RTM process, allowing better compensation for variability in permeability and viscosity.

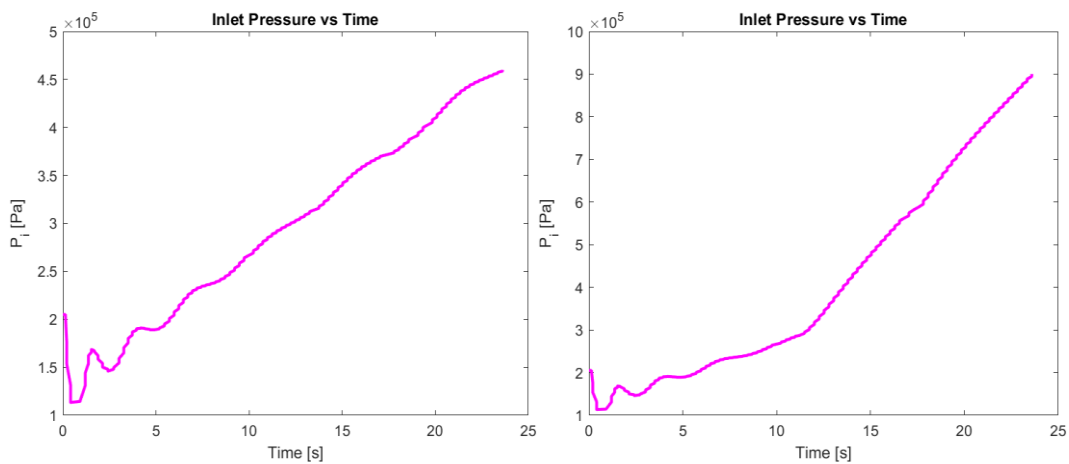
For a simple injection geometry (Figure 1), initial simulation results demonstrate that pressure-controlled flow can reduce variability in Darcy's velocity when constant velocity is the main control objective. For two cases of different permeability set ups, either uniform permeability or two different permeabilities in series, figures 2 and 3 show the deviation from the target velocity and the inlet pressure history to obtain constant velocity respectively. The control was based on the pressure readings from sensors at 6 distinct locations in the mould geometry. Future work will focus on experimental validation of the control model using embedded pressure sensors and videos of the flow front progression in a lab-scale RTM setup. The same approach will also be applied to more geometrically complex tools.



**Figure 1:** Schematic of the experimental mould



**Figure 2:** Deviation between target velocity and actual velocity after PID control; (left) Uniform permeability, (right) two regions of different but uniform permeability.



**Figure 3:** Inlet pressure controlled using PID control to maintain target velocity; (left) Uniform permeability, (right) two regions of different but uniform permeability.