CIMComp EPSRC Future Composites Manufacturing Research Hub

Fast algorithms for active control of mould filling in RTM process with uncertainties

Dr Mikhail Matveev (Mikhail.Matveev@nottingham.ac.uk), Dr Andreas Endruweit, Dr Marco Iglesias, Prof Andy Long, Prof Michael Tretyakov

Introduction

While idealised RTM processes are well understood, uncertainties such as material variability can in practice significantly affect the process. To minimise the effects of uncertainties on the RTM process, implementation of active control systems (ACS) is promising. However, the computational costs are the limiting factor in creating a real-time active control system (ACS) which can take into account the variabilities in the RTM.

Objectives

- Develop a computationally efficient Bayesian inversion algorithm for estimating permeability and porosity, which can be used for non-destructive examination (NDE) and for ACS.
- Implement and validate an ACS which can minimise variability in mould filling time and reduce formation of defects (dry spots) in the presence of material variability.

Regularizing Ensemble Kalman Algorithm (REnKA)

REnKA is based on a Bayesian inversion approach [1]. It utilises experimental data acquired during the mould filling to improve knowledge about the composite. It starts with prior distributions (initial guess) of the permeability and porosity and then gradually approximates posterior distributions, i.e. conditional distributions given observed data.

Algorithm steps (Fig. 1):

- Generate realisations (particles) from a prior;
- Simulate mould filling for each of the permeability and porosity realisations;
- Iteratively update particles to assimilate the observations;
- Calculate means and variability of permeability and porosity.

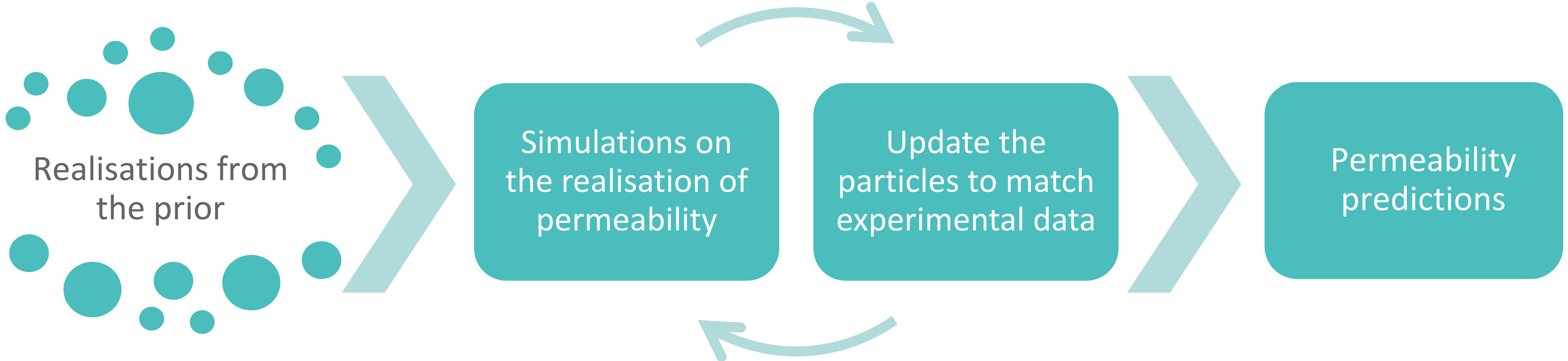

Figure 1. Schematic diagram for the Regularizing Ensemble Kalman Algorithm (REnKA).

Active control

REnKA for 2D problem is not yet feasible in a real time ACS. However, its 1D version is fast and accurate enough for an ACS. A virtual ACS based on 1D REnKA was implemented within ANSYS Fluent for a rectangular mould with three injection gates (Fig. 2).

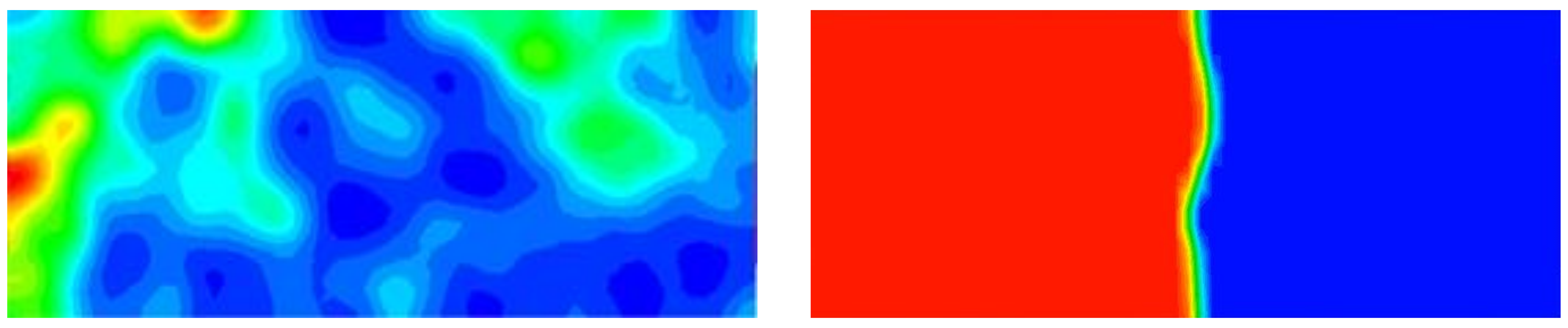

Figure 2. Random permeability distribution in preform (left); Flow front in the mould filling process (right).

The reference mould filling was designed to take 600 s for a preform with constant permeability and porosity. Quality of the ACS was defined as an average deviation of the flow front from a reference flow front position at reference time (Fig. 3).

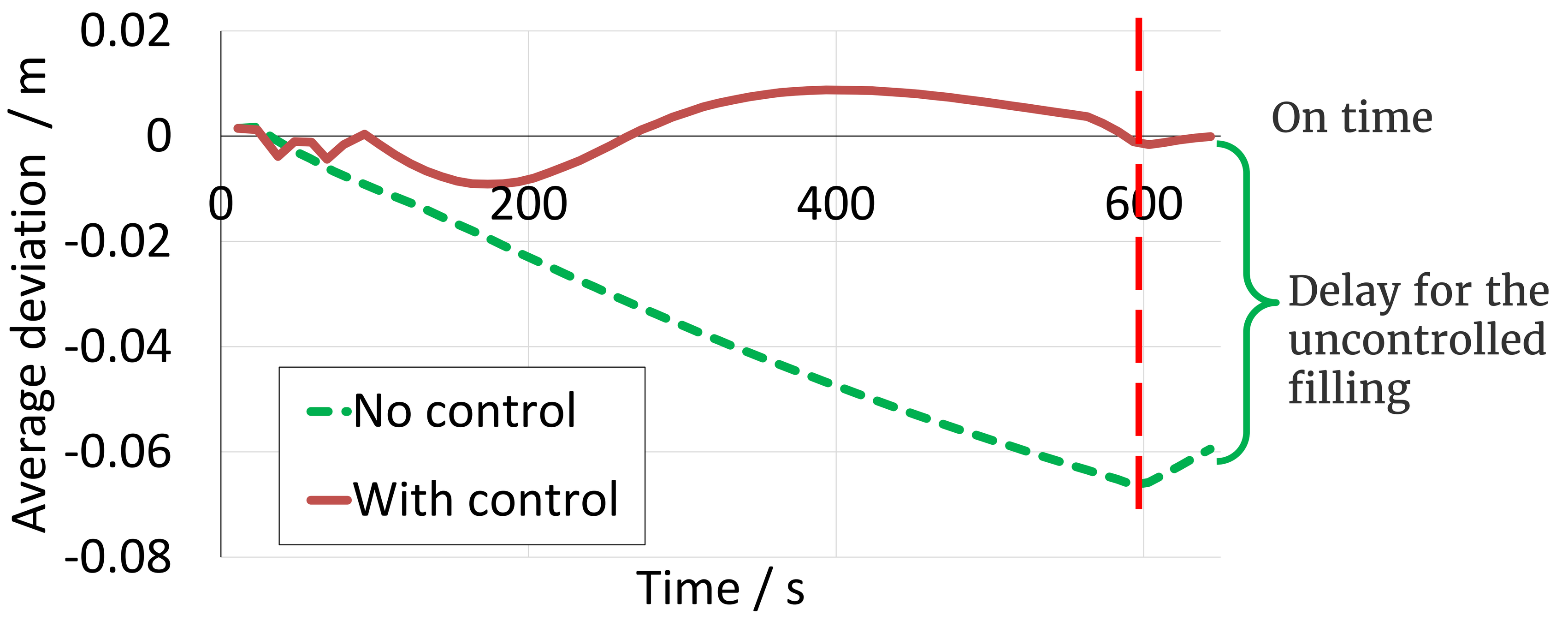

Figure 3. Average flow front deviation from the reference value in controlled and uncontrolled filling.

Post-processing of mould filling

Data collected during a moulding filling process can be used to estimate local fibre volume fraction by 2D REnKa (Fig. 4) and other properties of a composite as a part of NDE screening of the composite.

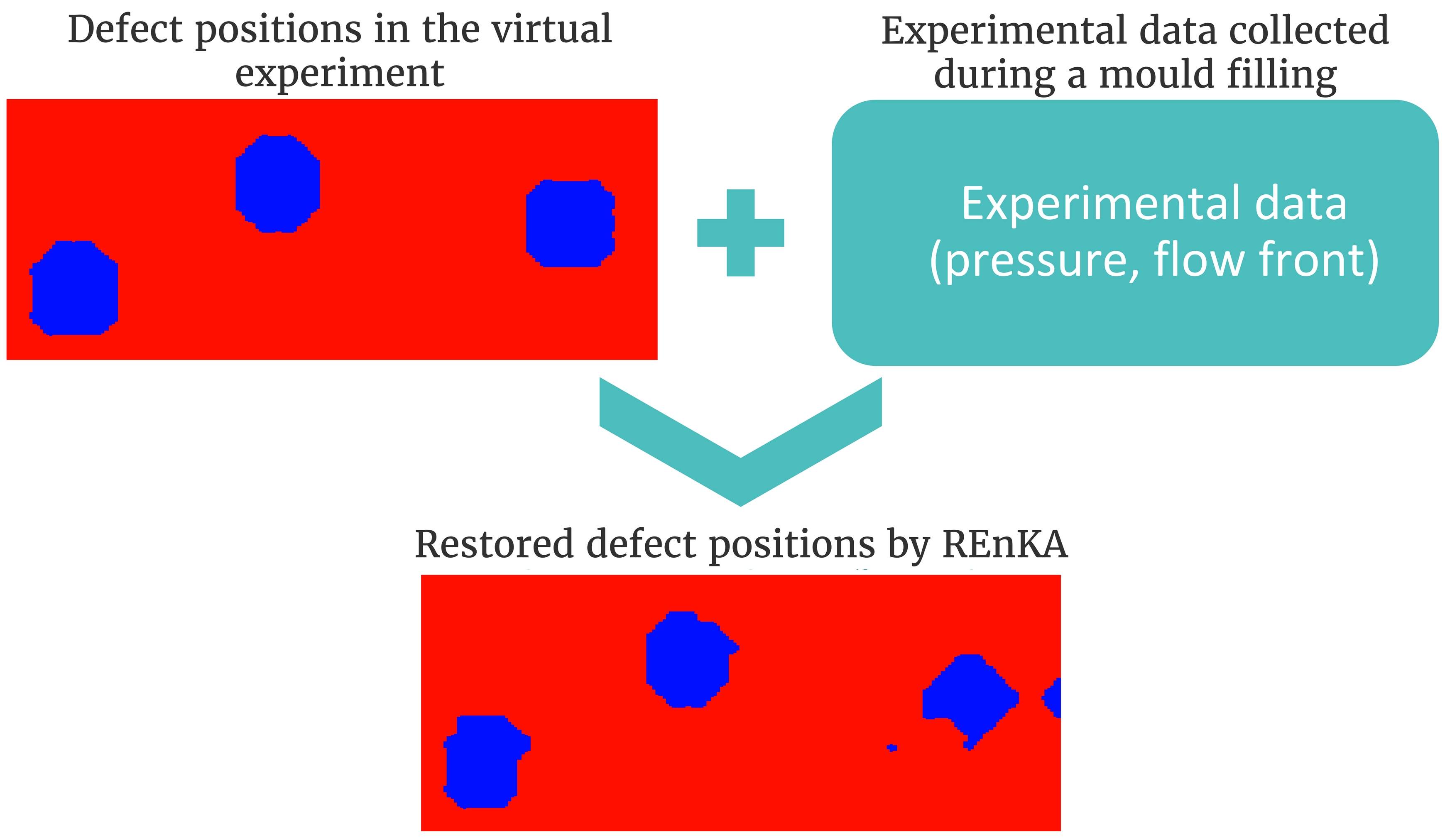

Figure 4. An example of post-processing of mould filling by REnKA.

Key findings

- A 1D implementation of REnKA employed within a virtual ACS showed a potential to mitigate variability of the mould filling process;
- A 2D implementation of REnKA was shown to restore permeability and porosity accurately.

[1] M. Iglesias, M. Park, M.V. Tretyakov. Bayesian inversion in resin transfer molding. *Inverse Problems*, to appear

This work was supported by the EPSRC through the Future Composites Manufacturing Research Hub [EP/P006701/1]

EPSRC Engineering and Physical Sciences Research Council

University of Bristol · Brunel University London · University of Cambridge · Cranfield University · The University of Edinburgh · University of Glasgow · Imperial College London · Manchester 1824 · University of Nottingham UK | China | Malaysia · University of Southampton