MICG Midlands Industrial Ceramics Group

Midlands Advanced Ceramics for Industry 4.0

CASE STUDY

Workstream 2: Digital Twin

REF No: 2406001

Revolutionising Ceramic Manufacturing: Integrating Artificial Intelligence for Precision and Innovation

Ceramic parts undergo shrinking and deformation as they go through high temperature sintering. This is necessary to develop the required performances but often unpredictable requiring additional work or waste of material and energy. The aim of this workstream is to improve efficiency and eliminate waste by developing a cutting-edge yet robust predictive method.

Working with Morgan and Rolls-Royce (industrial partners), the University of Leicester team has reinvented the finite element method by putting artificial intelligence (AI) at its heart. We established a two-step trained artificial neural network (ANN) to replace a nonlinear constitutive law in the finite element analysis of sintering deformation.

The ANN was firstly trained to learn the nonlinear constitutive law, followed by a retraining using limited experimental data.

This innovative approach is poised to seamlessly integrate machine learning into the heart of production processes, requiring only limited experimental data to enable a future where the quality, final shape and microstructural characteristics are accurately predicted by an AI digital twin before even emerging from the kiln. This approach promises to significantly reduce the uncertainties and inefficiencies that have been challenging the industry for decades.

At the heart of this potential improvement is a sophisticated digital twin (Fig. 1), superbly enhanced with AI capabilities, aiming to set a new standard in prediction accuracy.

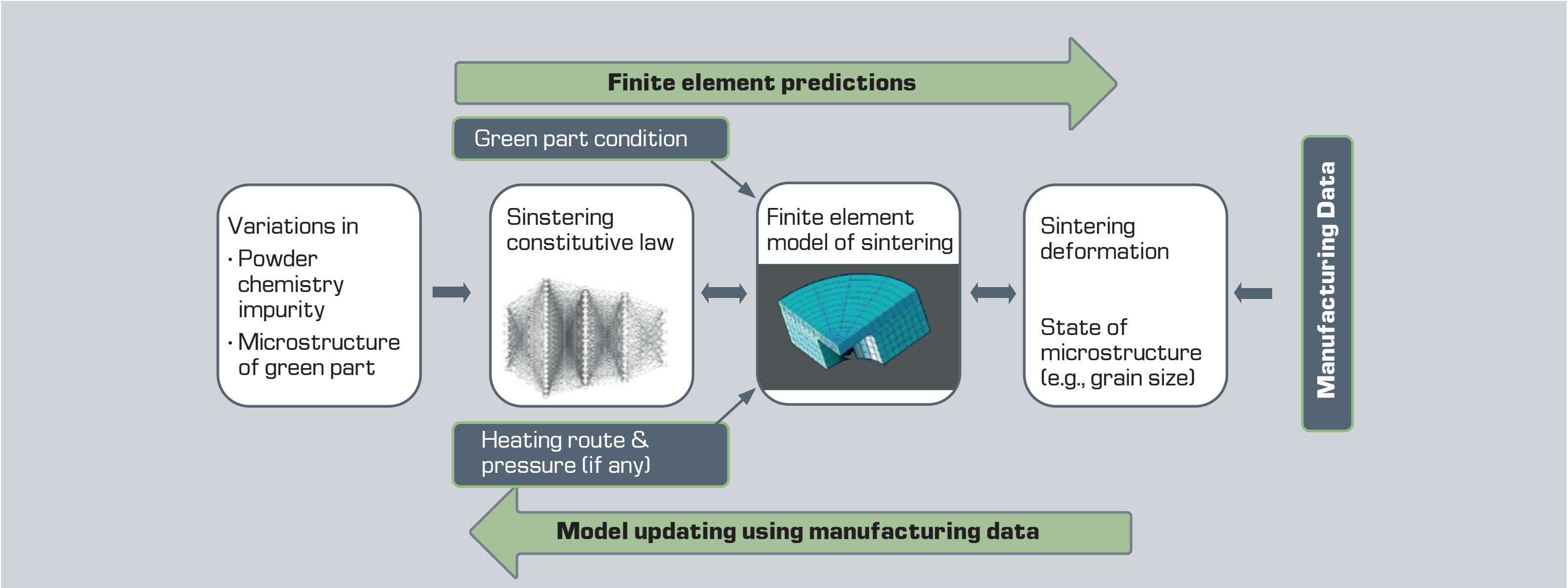

Figure 1. Illustration of digital twin for sintering of ceramics using artificial neural network.

Our AI-driven model is generic and can be used for a wide range of engineering processes. It embarks on its learning journey through a pioneering two-step training process of an ANN. First, the model learns the basic material behaviour, sort of like understanding the rules of the game, aka "constitutive law". The innovative step is in the second training, where the trained ANN is enriched and refined using limited real-world data from actual manufacturing. This innovative method is expected to enable our AI to become adept at understanding the actual material behaviour (Fig. 2).

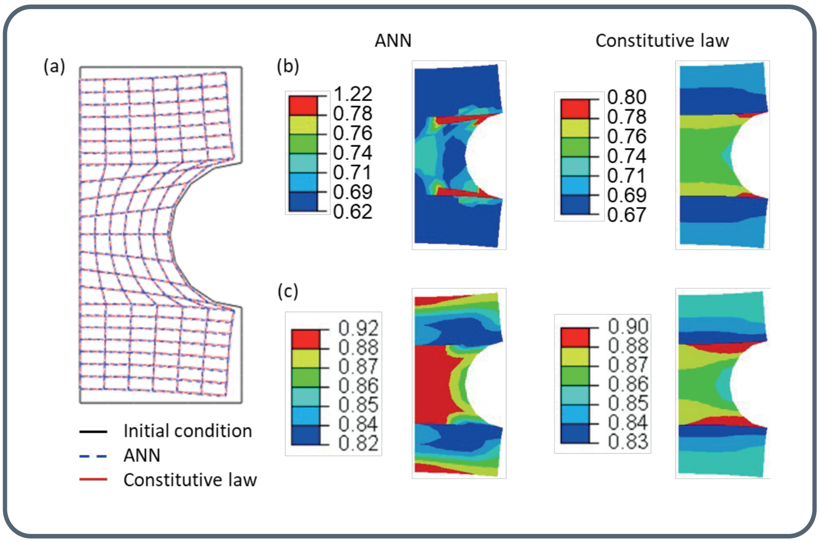

Figure 2. Comparison of sintering deformation (a) and spatial distributions of grain size (in µm; b) and relative density (c) after sintering that were obtained using (i) nonlinear constitutive law and (ii) ANN retrained using limited experimental data.

Furthermore, this cutting-edge modelling package is intended to serve as a vital bridge between potential industrial innovation and academic exploration.

It proposes a dynamic framework for engaging with manufacturing and computational modelling through AI, fostering a collaborative relationship between prospective commercial advancements and academic research. By blending innovation with tradition, we aim to craft not only visually stunning ceramics but also pieces of unmatched engineering precision, courtesy of AI.

Full results have been published in this open source paper
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Contact Details

Dr Ran He
Research Associate, University of Leicester
rh479@leicester.ac.uk

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