MICG Midlands Industrial Ceramics Group

Midlands Advanced Ceramics for Industry 4.0

CASE STUDY

REF No: 2505001

WS7 - Scale up

HIGH-RESOLUTION DILATOMETRY FOR DIGITAL TWIN MODELS

MODELLING & DESIGN | RAW MATERIALS PROCESSING | FORMING | DRYING & SINTERING | ANALYTICAL

INTRODUCTION

This study shows how dilatometry plays a pivotal role in bridging the gap between physical material behaviour and computational model for the application of a digital twin technology to simulate ceramic deformation. The goal is to create an accurate, dynamic digital representation of ceramic deformation under various firing profiles, materials and geometries, enabling predictive control over final part dimensions and minimising scrap due to deviation from tolerances.

THE CHALLENGE

Ceramic components are complex to model due to their highly variable behaviour during high-temperature processing. Key challenges include:

- **Concealed deformation during firing:** Monitoring shape changes in situ (i.e. inside the kiln at firing temperature) is technically challenging.
- **Sensitivity to process variation:** Even small deviations in powder formulation or compaction can lead to substantial differences in densification and shrinkage.
- **Precision requirements:** Final parts often demand millimetre or even micrometre- level tolerances, necessitating a high-fidelity approach to predicting deformation.

These issues are compounded by the fact that ceramic shrinkage is non-linear, temperature-dependent, and often anisotropic — all of which must be captured in the digital model.

THE APPROACH

To validate and train the digital twin simulation, a scenario was designed using iso-pressed green bodies of varying geometries, fired under identical thermal conditions. A model was trained using deformation data from a reference geometry and then applied to predict deformation in other geometries, testing its generalisability.

THE ROLE OF THE DILATOMETER

High-resolution dilatometry was essential for acquiring accurate shrinkage and sintering kinetics data. To this end, a **Netzsch DIL 402** dilatometer with a resolution of **1 nm** was used. This instrument is capable of reaching temperatures up to **1600 °C** under various atmospheres, including **air, nitrogen, and argon,** and can accommodate samples sized **6-8 mm** in **diameter 2-50 mm** in **length.**

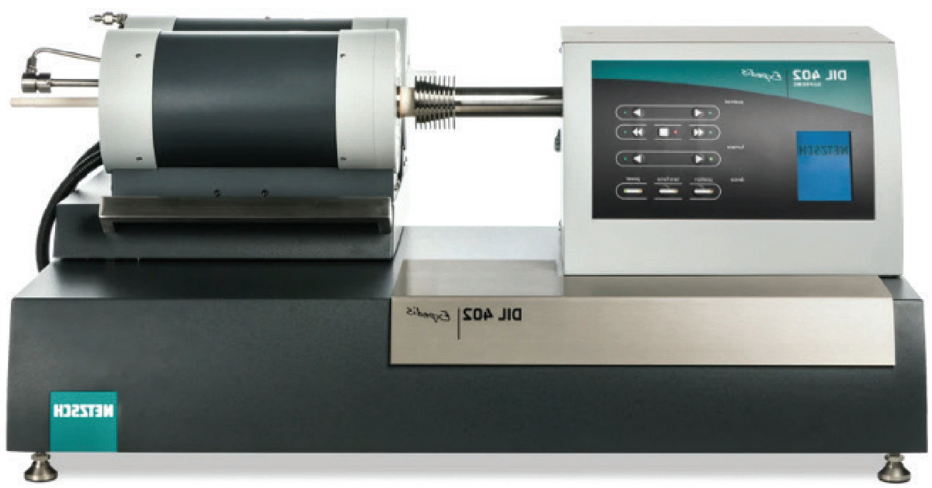

Figure 1

Horizontal push-rod dilatometer (Netzsch DIL 402 Expedis) used for measuring dimensional changes of materials as a function of temperature.

By conducting tests across a range of heating rates and temperature profiles, we obtained:

- **Thermal expansion and shrinkage curves**
- **Sintering onset and densification rates**

These data sets were foundational for training the simulation engine, allowing it to incorporate real-world material behaviour rather than rely on idealised assumptions.

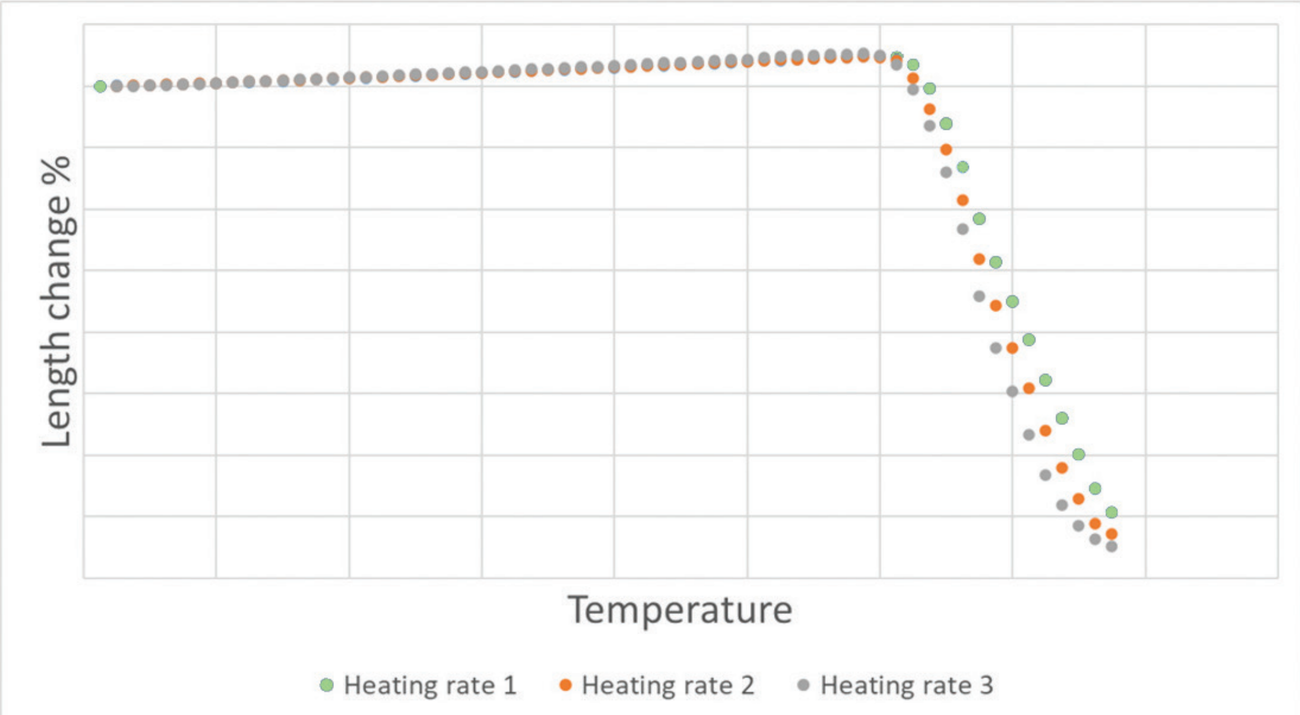

Figure 2

Example of dilatometry data

OUTCOMES DELIVERED

- Comprehensive dilatometry datasets obtained using the **Netzsch DIL 402**, covering a temperature range of 25°C-1500°C over heating rates from 0.5°C /min to 10°C /min.
- A validated dataset of shrinkage behaviour for the ceramic material under multiple thermal conditions.
- Improved model accuracy in predicting deformation across multiple geometries.

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This work was supported and partly funded by UK Research and Innovation through the Strength in Places Fund Programme. Midlands Advanced Ceramics for Industry 4.0