

Nested Machine Learning in Finite Element Analysis for Predicting Sintering Deformation

Dimensional distortion during sintering remains a major challenge in ceramic manufacturing, frequently leading to costly post-sintering machining or component rejection. Reliable prediction of shrinkage and shape change is difficult because sintering behaviour depends on evolving microstructure, thermal history and processing conditions, whilst conventional constitutive models require extensive calibration that is rarely practical.

Our work presents a machine learning-based finite element (FE) framework for predicting sintering deformation that is directly relevant to ceramic processing and manufacturability. Rather than relying on fixed empirical material models, the approach integrates artificial neural networks (ANNs) to adaptively represent sintering behaviour within a physics-based simulation. A universal nested backpropagation algorithm enables ANNs to be trained when nested in FE analysis using manufacturing-scale measurements.

The methodology is demonstrated for ceramic sintering, with flash sintering included to illustrate applicability under non-uniform electrical and thermal conditions. The results show substantially improved prediction of shrinkage and distortion compared with empirical material models, enabling more reliable assessment of dimensional accuracy during process design. The framework supports the development of practical digital twins for sintering, offering a route to reduce distortion, improve yield and optimise ceramic manufacturing processes.

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Yes

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