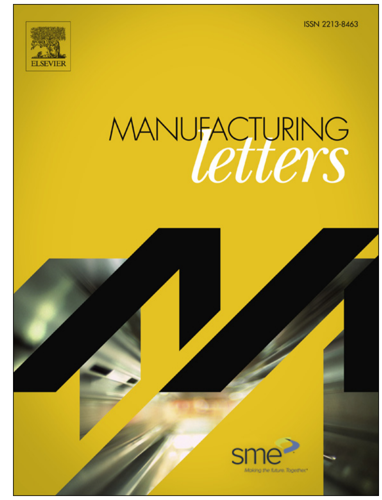
Accepted Manuscript



Letters

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PII: S2213-8463(18)30005-1
DOI: https://doi.org/10.1016/j.mfglet.2018.01.002
Reference: MFGLET 125

To appear in: *Manufacturing Letters*

Received Date: 22 September 2017
Revised Date: 9 January 2018
Accepted Date: 10 January 2018

Please cite this article as: A. Koeppe, C.A.H. Padilla, M. Voshage, J.H. Schleifenbaum, B. Markert, Efficient numerical modeling of 3D-printed lattice-cell structures using neural networks, *Manufacturing Letters* (2018), doi: https://doi.org/10.1016/j.mfglet.2018.01.002

Efficient numerical modeling of 3D-printed lattice-cell structures using neural networks

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Additively manufactured structures can be tailor-made to optimally distribute mechanical loads while remaining light-weight. To efficiently analyze the locally unique mechanical behavior of structures made from a large number of small lattice cells, a strategy which employs neural networks and deep learning to predict the maximum stresses in the realm of linear elasto-plasticity of a detail-level finite-element model is presented. The strategy is demonstrated on a single lattice cell specimen. Good agreements between experimental, finite element and neural network results are found at a significant reduction in computation time.

Keywords: structural mechanics; neural networks; additive manufacturing; multi-scale modeling

Introduction

Additive manufacturing enables the production of light-weight components from micro- and nanoscale structures, such as lattice cells, tailor-made to optimally support the structures loading conditions. To find the optimal geometry at every point of the component, finite element simulations at detail level imply a large number of degrees of freedom to accurately resolve each lattice cell, which severely increases computation time.

For components made from materials with a regular micro- and nanostructure, multi-scale approaches using homogenization can reduce the degrees of freedom and computation time using a reference volume element over a smeared domain. Due to the unique lattice cell at every point of the component, a large number of unique reference volume elements would be necessary, which counteracts the performance gains.

The long-term objective of this research is a novel multi-scale strategy able to parameterize each unique lattice cell, independent of its geometrical sizes, by using (artificial) neural networks (NN). This strategy will enable efficient simulations and topology optimization of large 3D-printed structures with locally unique microstructure. In the scope of this work, we propose a strategy employing a neural network to learn a parameterized mechanical model of a reference lattice-cell structure with a linear elasto-plastic