Influence of the miniaturization effect on the effective stiffness of lattice structures in additive manufacturing

Guillaume Meyer[1),*)], Florian Brenne[2),)], Alexander Großmann[1)], Thomas Niendorf[2)] and Christian Mittelstedt[1)]**

[1)] Technische Universität Darmstadt, Konstruktiver Leichtbau und Bauweisen
Otto-Berndt-Straße 2, 64287 Darmstadt, Germany

[2)] Universität Kassel. Institut für Werkstofftechnik
Mönchebergstraße 3, 34125 Kassel, Germany

[*)] Corresponding author: guillaume.meyer@klub.tu-darmstadt.de

[**)] Current address: University of Illinois at Urbana-Champaign
Department of Mechanical Science and Engineering
1206 W Green St, Urbana, IL 61801, USA

ABSTRACT

Thin-walled and cellular structures have a high lightweight potential due to their advantageous stiffness to weight ratio. They find particular interest in the field of additive manufacturing due to easy and reproducible manufacturing. However, the mechanical performance of such structures depends heavily on the manufacturing process and the resultant geometrical imperfections (porosity, strut thickness, waviness) for which a global understanding of their influence is needed.

Many authors conduct empirical investigations whereas analytical methods are rarely applied. In order to obtain efficient design rules considering both mechanical properties and process aspects analytical descriptions are most desirable. Most available analytical models for the determination of effective properties are based on straightforward beam theories and ignore manufacturing influences that strongly impact the mechanical properties of additively manufactured thin-walled structures. One characteristic of thin walled structures is the miniaturization effect, which leads to reduced stiffness and strength with decreasing feature dimensions and, thus, significantly influences the elasto-plastic properties of lightweight-relevant structures.

This contribution highlights the need to quantify further microstructural effects and to encourage combining them into mesostructural approaches in order to assess macrostructural effective properties. This multi-scale analysis of lattice structures is performed through a comparison between effective stiffnesses obtained through an analytical approach and conducted experiment of lattice structures, coupled with an investigation of the microstructural characteristics of their struts. In order to cover different potential loading scenarios, bending-dominated and stretching-dominated lattice structures made of the commonly used materials 316L and Ti6Al4V are considered, whereby differences in solidification and cooling properties are also considered.