Multiscale experimental and numerical analysis of 3D-printed IN718 BCCZ lattice structures

L. Barriere*, B. Filloux*†, M. Suard*, S. Perusin*, P. Lhuissier**

* Institute of Research and Technology Saint Exupéry, B612, 3 rue Tarfaya, 31400 Toulouse, France
e-mail: ludovic.barriere@irt-saintexupery.com, web page: http://www.irt-saintexupery.com

† Altran Technologies, 17 Avenue Didier Daurat, 31700 Blagnac

** Univ. Grenoble Alpes, CNRS, Grenoble INP, SIMAP, F-38000 Grenoble, France

ABSTRACT

Mechanical behaviour of 3D-printed metallic lattice structures has been widely explored in the recent years [1, 2]. In particular, compression is the most common loading of interest as it is quite simple to achieve. However, it has been shown that the response of samples is very sensitive to boundary conditions (friction, free faces), especially in the case of BCCZ geometry (BCC + vertical struts) where shear bands may only occur in the 45° plane between free faces [3]. From the modelling standpoint, a straightforward approach is to consider constitutive behaviours of unitary struts depending on their orientation (vertical/35°) into a 1D or 3D beam representation of lattice structure [4] but few studies rely on mechanical testing of such unitary thin components [5]. Some authors account also for some geometrical defects due to AM process as non-circular section of inclined struts, strut waviness, radius variation or porosity fraction [6]. Whereas these parameters allow for representation of very influencing imperfections, their combinations are not analysed together and local effects of strut connexions (nodes) may not be well captured by 1D equivalent beam models.

In the present study, authors are first focusing on relevance of characterization of unitary thin components, including struts and nodes extracted from BCCZ lattice structure, as inputs for predictive lattice structure models. A modelling approach is proposed accordingly accounting for local behaviours and a 3D to 1D equivalent analysis is performed for adjustment of node bending stiffness. Simulations are compared with experimental compression and shear tests of lattice structures with different shape ratios (in terms of number of cells) instrumented with high definition 3D-Digital Image Correlation.

REFERENCES

[1] Suard, M. et al., *Mechanical equivalent diameter of single struts for the stiffness prediction of lattice structures produced by Electron Beam Melting.* Additive Manufacturing, vol 8, p.124–131, 2015

[2] Leary, M. et al., *Inconel 625 lattice structures manufactured by selective laser melting (SLM): Mechanical properties, deformation and failure modes.* Materials and Design, vol 157, p. 179–199, 2018

[3] Vanderesse, N. et al., *Measurement of deformation heterogeneities in additive manufactured lattice materials by Digital Image Correlation: Strain maps analysis and reliability assessment.* Journal of the Mechanical Behavior of Biomedical Materials, 86, p. 397–408, July 2018

[4] Tancogne-Dejean, T. and Mohr, D. *Stiffness and specific energy absorption of additively-manufactured metallic BCC metamaterials composed of tapered beams*, International Journal of Mechanical Sciences, vol. 141, p. 101–116, March 2018

[5] M. Smith et al, *Finite element modelling of the compressive response of lattice structures manufactured using the selective laser melting technique*, Int. J. Mech. Sci., vol. 67, p. 28‑41, Febr. 2013.

[6] Campoli G. et al., *Mechanical properties of open-cell metallic biomaterials manufactured using additive manufacturing*. Materials & Design, vol 49, p.957–965, 2013