Material characterization of additively manufactured complex steel components

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ABSTRACT

The production of complex customized 3D printed steel structures has drawn significant interest in industry and research due to its extended range of application and high flexibility. However, the complexity of the manufacturing process puts uncertainty on the confidence levels of the end product material properties. The mechanical behavior of such structures is highly influenced by the process parameters, process-induced porosity state and geometrical deviations of the internal microstructures.

In this work, numerical characterization methods are developed to efficiently evaluate mechanical parameters of additively manufactured porous metal structures. In order to resolve micro-architectured parts in great detail, an application of a conventional Finite Element Method is impractical due to the infeasible costs of mesh generation. Thus, the high-order Finite Cell Method [1] is utilized to establish an efficient extraction of material parameters directly from the provided 3D models stemming from CT-Scans or from CAD. In order to determine linear elastic mechanical characteristics a first-order numerical homogenization [2,3] method is applied and verified against a direct numerical experiment at full scale. Numerical results are then validated against the experimental tests performed on sample specimens. It will also be shown that imaging artifacts arising from scanning of dense metallic structures, e.g. beam hardening, partial volume and aliasing, may significantly influence the quality of the presented workflow. Additionally, Darcy's permeability and fatigue characteristics of porous structures are investigated. Finally, an estimate on the sensitivity of the obtained material characteristics to a stochastic variation of the micro-structural geometrical characteristics is investigated.

REFERENCES

[1] Düster, A., Rank, E. and Szabó, B. *The p-Version of the Finite Element and Finite Cell Methods*. Encyclopedia of Computational Mechanics Second Edition:1–35, (2017).

[2] Heinze, S., Joulaian, M. and Düster, A. *Numerical homogenization of hybrid metal foams using the finite cell method*. Computers and Mathematics with Applications, 70(7):1501 – 1517, (2015).

[3] Hain, M. and Wriggers, P. *Numerical homogenization of hardened cement paste*. Computational Mechanics, 42(2):197 212, (2008).