Numerically aided 3D printed porous materials almost attaining the Hashin-Shtrikman bounds

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Key Words: *Additive manufacturing, Representative Volume Element, Homogenization, Random Porous Materials.*

This work aims to introduce a methodology that allows for the combination of 3D-printing, experimental testing, numerical and analytical analysis of random porous materials with controlled homogenized elastic properties. These microstructures are computer-generated based on a random sequential addition algorithm [1] with statistically controlled morphological properties such as volume fraction, shape and size of voids as well as isotropic distribution of their centers. We first focus on porous materials containing single-size (monodisperse) spherical voids. The porous specimens are fabricated by 3D printing with polymer jet technology whereas their microstructure is aposteriori re-evaluated by optical microscopy and SEM. The influence of the 3D printing process parameters is also experimentally checked. An experimental setup is developed starting from the determination of a volume element cell that ensures the representativity of the elastic mechanical properties of the material irrespectively of the applied boundary conditions [2]. This representative volume element cell is then used to create an experimental sample that fits the dogbone standards for relaxation tests. These porous specimens are then tested with a multistep relaxation procedure to retrieve their pure linear elastic properties. The effective experimental elastic moduli are compared to numerical simulations and analytical results [3] and are shown to approach the Hashin-Shtrikman bounds for porosities up to 30%.

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