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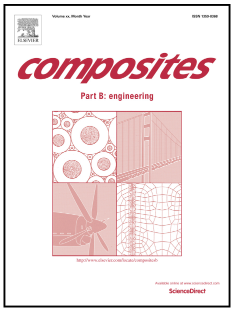

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Numerically-aided 3D printed random isotropic porous materials approaching the Hashin-Shtrikman bounds

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Abstract

The present study introduces a methodology that allows to combine 3D printing, experimental testing, numerical and analytical modeling to create random closed-cell porous materials with statistically controlled and isotropic overall elastic properties that are extremely close to the relevant Hashin-Shtrikman bounds. In this first study, we focus our experimental and 3D printing efforts to isotropic random microstructures consisting of single-sized (i.e. monodisperse) spherical voids embedded in a homogeneous solid matrix. The 3D printed specimens are realized by use of the random sequential adsorption method. A detailed FE numerical study allows to define a cubic representative volume element (RVE) by combined periodic and kinematically uniform (i.e. average strain or affine) boundary conditions. The resulting cubic RVE is subsequently assembled to form a standard dog-bone uniaxial tension specimen, which is 3D printed by use of a photopolymeric resin material. The specimens are then tested at relatively small strains by a proper multi-step relaxation procedure to obtain the effective elastic properties of the porous specimens.

Keywords: Additive manufacturing, Hashin-Shtrikman bounds, Random Sequential Adsorption, Random composites, Homogenization, Porous Materials, Effective properties

1. Introduction

Porous materials are present in nature (e.g., rocks and geomaterials) but can also be designed to allow for controlled stiffness of lightweight structures. In the literature, one can recognize two main categories of porous materials; materials with closed-cell porosity, i.e. non-interconnecting voids, and open-cell porosity, which comprises most lattice and foam materials. In particular, this latter class of composites has been extensively studied in an effort to adapt the physical properties of their microstructure or micro-architecture (Fleck et al., 2010) by controlling morphological features of the internal geometry (Gibson and Ashby, 1997; Deshpande and Fleck, 2000). Such open-cell porous materials find applications in high-stiffness lightweight

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