Contribution ID: **6**

Type: **Oral 20 Minutes**

Effective elastic properties of porous media and metamaterials

Wednesday, 16 May 2018 09:32 (15 minutes)

Porous media can be viewed as a special type of two-phase composites (with one phase being the void phase or possibly vacuum) or as metamaterials (i.e. materials with microstructures that are principally similar to macroscopic architectural structures, from which they differ only by scale) [1,2]. In this contribution we investigate the effective elastic constants of isotropic and cubic porous media or metamaterials. The computer-generated digital microstructures studied include convex pores (spherical, spheroidal-oblate, spheroidal-prolate), concave pores (i.e. intergranular voids between spherical or spheroidal grains), and foams (strut-based or wall-based Kelvin or random foams with open or closed cells). Numerical calculations are used to obtain the effective constants (stiffness matrix) of these model microstructures. The results are compared to the micromechanical bounds (upper Wiener-Paul and upper Hashin-Shtrikman bounds) and to the admissible predictive model relations (i.e. power-law relations and our exponential relations [3-5]; other model relations occuring in the literature are shown to be either redundant or wrong, and it is shown that so-called minimum solid area model are useless for the prediction of effective elastic properties of materials with concave pores [6]). While the power-law and exponential relations provide tentative predictions that are more or less realistic for the effective elastic properties of materials with convex pores and foams, they are seriously in error for materials with concave pores, grossly overestimating the true values. In order to circumvent the (highly nontrivial) problem of quantifying a large number of microstructural descriptors and the (so far unsolved) problem of implementing this microstructural information into microstructure-property relations, cross-property relations between the elastic moduli and thermal conductivity can be used. In particular, it is shown that our cross-property relation for spherical pores [7] provides excellent predictions of the tensile modulus (Young' s modulus) and shear modulus in all cases of isometric pores, spherical or not, including the case of concave pores, which cannot be predicted by any analytical model relation. Moreover it is shown that our recently proposed generalized cross-property relation for spheroidal pores [8] can predict the elastic properties even in the case of randomly oriented anisometric (spheroidal) pores.

References

1. Berger J. B., Wadley H. N. G., McMeeking R. M.: Mechanical metamaterials at the theoretical limit of isotropic elastic stiffness, Nature 543, 533-537 (2017).
2. Ai L., Gao X. L.: Metamaterials with negative Poisson's ratio and non-positive thermal expansion, Composite Structures 162, 70-84 (2017).
3. Pabst W., Gregorová E.: Elastic and thermal properties of porous materials –rigorous bounds and cross-property relations, Mater. Sci. Technol. 31, 1801-1808 (2015).
4. Pabst W., Gregorová E.: Conductivity of porous materials with spheroidal pores, J. Eur. Ceram. Soc. 34, 2757-2766 (2014).
5. Pabst W., Gregorová E.: Young's modulus of isotropic porous materials with spheroidal pores, J. Eur. Ceram. Soc. 34, 3195-3207 (2014).
6. Pabst W. Gregorová E.: Minimum solid area models for the effective properties of porous materials –a refutation, Ceram. Silik. 59, 244-249 (2015).

7. Pabst W., Gregorová E.: A cross-property relation between the tensile modulus and the thermal conductivity of porous materials, Ceram. Intern. 33, 9⊠12 (2007).
8. Pabst W., Gregorová E.: A generalized cross-property relation between the elastic moduli and conductivity of isotropic porous materials with spheroidal pores, Ceram. Silik. 61, 74-80 (2017).

Acceptance of Terms and Conditions

Click here to agree

Primary authors: PABST, Willi (University of Chemistry and Technology, Prague); Dr GREGOROVÁ, Eva (University of Chemistry and Technology, Prague); Ms UHLÍŘOVÁ, Tereza (UCT Prague)

Presenter: PABST, Willi (University of Chemistry and Technology, Prague)

Session Classification: Parallel 6-H

Track Classification: MS 2.15: Modelling and Simulation of Porous Media: From Microstructure to Functionality