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Size-dependent elastic properties of micro- and nano-open-celled foams

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Summary

This paper aims to study the size-dependent elastic properties of micro- and nano-sized open-celled foams. To simplify the analysis, we use perfect regular body-centered cubic structure (i.e. BCC foam), which has cubic symmetry and only three independent elastic constants. Taking strut bending, twisting and axial compression/stretching as the deformation mechanisms, Zhu, Knott and Mills (JMPS, V45, pp. 319-343, 1997) have obtained closed form results of all the three independent elastic constants (i.e. the Young's modulus E11 , the shear modulus G12 and the Poisson ratio v12) as functions of the bending stiffness, the torsional stiffness and the compression/stretching stiffness of the cell struts. They also obtained the closed form result of the Zener's anisotropy factor A and found that low density regular BCC foams are nearly isotropic (i.e. A is close to 1.0). For conventional BCC open-celled forms with uniform cell struts, they found that the dimensionless Young's modulus, shear modulus and Poisson ratio only depend on the shape of the cross-section of the struts and the foam relative density. However, these dimensionless results may not apply to their micro- and nano-counterparts because of the strain gradient effect at micrometer scale and the surface elasticity and initial stress effects at nanometer scale.

In this paper, using the general expressions obtained by Zhu et al. (JMPS, V45, pp. 319-343, 1997) and the size-dependent bending stiffness, torsional stiffness and axial compression/stretching stiffness of the cell struts at micrometer or nanometer scale, we have obtained the results for the three independent elastic constants and the Zener's anisotropy factor and found that they are strongly size-dependent. Generally, the thinner the cell struts or the smaller the cell size (if the foam relative density if fixed), the larger will be the dimensionless Young's modulus and shear modulus. All the dimensionless elastic constants reduce with the increase of the foam relative density. The results show that a micro- or nano-sized open-celled foam could exhibit a negative Poisson's ratio. For nano-sized open-celled foams, the dimensionless Young's modulus and shear modulus can be controlled to vary over a range around 66%. The obtained results are very interesting and of important practical applications.