Modeling microstructure of solid foam using random Kelvin open-cells – Influence of boundary parameters and cell strut cross-section

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Abstract

Based on experimental observations of open-cell foams, the random Kelvin open-cell structure is a good approximation of their microstructure. The present study adopts this geometry and employs it to establish representative volume elements (RVEs) in order to model the microstructure and mechanical response of such foams. A single Kelvin cell, an assembly of identical Kelvin cells, and an assembly of Kelvin open-cells with a degree of randomness in strut lengths and strut connection angles, were modeled using finite elements, and their response to gross compression is simulated. Observations indicate that the random Kelvin cell assembly resembles actual solid foams more closely than the assembly of identical Kelvin cells. However, simulation results show that the yield strengths of both the identical and random cell assemblies do not differ significantly. The primary difference in the load-deformation or stress-strain response occurs during transition from the post-yield plateau phase to final densification. For a finite number of cells in an RVE assembly to represent and emulate an actual foam sample comprising cell numbers several orders of magnitude larger, several boundary conditions were examined to identify the most appropriate one. Simulations of quasi-static compression of the corresponding FEM models – i.e. with fixed, free and periodic boundary conditions, were undertaken and the results compared and analyzed. They show that the RVE with a periodic boundary condition exhibits a ‘C’-shaped or an ‘S’-shaped profile, which is consistent with experimental observations reported. Secondly, the quasi-static compressive response of RVEs comprising cell struts with different cross-sections, such as a circle, triangle, square and Plateau border profile, were examined. The results show that for a common cross-sectional area, the yield strength corresponding to the RVE with a plateau border cross-section is significantly larger than those with the other three strut cross-sections. This is because the second-moment of area of the plateau border is significantly higher, thus increasing the flexural stiffness of the strut, and thus the cell. The results also indicate that the predicted compressive strengths of open-cell foam modeled by RVEs using cell struts with a circular cross-section, are likely to significantly underestimate actual values. Finally, the random Kelvin open cell assembly, comprising struts with a plateau border cross-section and periodic boundary conditions, was used to simulate quasi-static compression of an open-cell polymeric foam. The simulations results agree well experimental data, indicating the potential and applicability of this model to capture the mechanical response of such foams.