A COMPUTATIONAL STUDY TOWARD DETERMINING FOAM RVE SIZE

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Cellular solids are ubiquitous in nature (e.g. wood, bone), and have been found increasingly valuable in meeting the material demands of an expanding suite of specialized engineering applications (e.g. honeycombs, foams). These materials have unique characteristics relative to more common structural materials, including complex, irregular structure at the cellular scale, i.e. the microstructure. Recent research on polymeric foams is advancing modeling, simulation, and analysis capabilities applicable to system components in use at Los Alamos National Laboratory.

Polymeric foams are light-weight structural components with unique mechanical properties and applications. They are used in packaging to isolate components and absorb energy. They routinely operate over a large range of compressions in service. Well-established "rules of thumb" exist for estimating foam bulk mechanical response from parent material properties and a few basic characteristics of the cellular microstructure. However, the range of mechanical response measured for nominally identical foams clearly indicates that additional characteristics are important.

While this would seem to be a promising scenario for contributions via computational mechanics, the simulation of foams is a well-established computational challenge for several reasons: (1) The deformations of interest are large, both bulk and on the cellular scale, (2) extensive "self contact" must be simulated as the microstructure collapses upon itself, and (3) realistic foam microstructures are irregular and difficult to discretize using a body-fit mesh. This combination of challenges has limited many modeling efforts to small deformations and idealized microstructures.

Recent developments in particle-in-cell (PIC) methods indicate that these numerical techniques are suitable for precisely this class of problem. Using microstructures determined via x-ray microtomography, quasi-static compression was simulated with results in agreement with experimental data in the literature. It was predicted that a particular open-celled foam is an auxetic material at modest compressions, and that it becomes progressively more difficult to remove porosity, resulting in residual porosity even when nominally fully densified [1].

More recently image analysis has been used to identify and track microstructural features such as strut length and cell volume. Variations in microstructural features, average compressive response, and stress and strain state statistics, are being compared in order to 1) determine the quantity of material required to produce mechanical response representative of bulk foam, i.e. determine the Representative Volume Element (RVE) size, and 2) characterize foam deformation in detail and identify the features which affect bulk response. RVE size is found to depend strongly on the diagnostic examined for convergence.

An approach to developing bulk foam constitutive models, in which bulk response is obtained from unit cell mechanics models, foam structure statistics, and variations in average response, will also be presented in this minisymposium. The simulations and analyses described here target calibration of this theory, providing a general methodology for bridging microstructural and continuum material scales in cellular solids.

References

[1] A. D. Brydon, and S. G. Bardenhagen, "Simulation of the densification of real open-celled foam microstructures", *J. Mech. Phys. Solids*, **53**, 2638-2660, 2005.

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