Abstract

Energy return in footwear is associated with the damping behavior of midsole foams, which stems from the combination of cellular structure and polymeric material behavior. Recently, traditional ethyl vinyl acetate (EVA) foams have been replaced by BOOST(TM) foams, thereby reducing the energetic cost of running. These are bead foams made from expanded thermoplastic polyurethane (eTPU), which have a multi-scale structure consisting of fused porous beads, at the meso-scale, and thousands of small closed cells within the beads at the micro-scale. Existing predictive models coarsely describe the macroscopic behavior but do not take into account strain localizations and microstructural heterogeneities. Thus, enhancement in material performance and optimization requires a comprehensive understanding of the foam’s cellular structure at all length scales and its influence on mechanical response. This dissertation focused on characterization and deformation behavior of eTPU bead foams with a unique graded cell structure at the micro and meso-scale. The evolution of the foam structure during compression was studied using a combination of in situ lab scale and synchrotron x-ray tomography using a four-dimensional (4D, deformation + time) approach. A digital volume correlation (DVC) method was developed to elucidate the role of cell structure on local deformation mechanisms. The overall mechanical response was also studied ex situ to probe the effect of cell size distribution on the force-deflection behavior. The radial variation in porosity and ligament thickness profoundly influenced the global mechanical behavior. The correlation of changes in void size and shape helped in identifying potentially weak regions in the microstructure. Strain maps showed the initiation of failure in cell structure and it was found to be influenced by the heterogeneities around the immediate neighbors in a cluster of voids. Poisson’s ratio evaluated from DVC was related to the microstructure of the bead foams. The 4D approach taken here provided an in depth and mechanistic understanding of the material behavior, both at the bead and plate levels, that will be invaluable in designing the next generation of high-performance footwear.