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Modeling of ordered foam topologies with maximal stiffness

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ABSTRACT

Recent advances in direct manufacturing open the door for promising materials, such as ordered structural foams. Reduced bending in closed cell stochastic foams, compared with open cell, gives rise to substantially higher stiffness and strength. Closed cell ordered foams similarly outperform lattice materials and can achieve theoretical bounds for stiffness (Hashin and Shtrikman, 1963). Mechanical models for the stiffness of foams (Gibson, 1989 & Grenestedt, 1999) and theoretical bounds are used as metrics to compare a variety of topologies. Representative volume element finite element modeling is used to calculate strain energy distributions to identify topological features common in high performance designs. Three classes of materials are identified: maximal performance designs with a total stiffness that approaches theoretical bounds at low relative densities, a high performance stretch dominated group, and a compliant group with high mesoscale configurational entropy. A variety of established and novel topologies are considered that largely represent the performance of stiff mesoscale ordered materials, eliciting a wide range of anisotropy, over the range of low to intermediate relative densities.