Plastic Anisotropy of Elastically-isotropic Beam, Shell and Plate Networks: Theory and Experiments

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Plastic Anisotropy of Elastically-isotropic Beam, Shell and Plate Networks: Theory and Experiments

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It is shown through combined theoretical and numerical analysis that elastically isotropic mechanical metamaterials of cubic symmetry may be configured as a periodic network composed of either beams, shells or plates. Optimality is achieved through plate networks only, in the sense, that they reach the theoretical Hashin-Shtrikman bounds for the elastic moduli for a given relative density. However, from the point of view of multi-functionality, fatigue strength, impact energy absorption and ease of manufacturing, the use truss lattices and periodic smooth shell structures is still attractive. In addition to deriving the effective yield surfaces through homogenization, this talk discusses the plastic anisotropy of elastically-isotropic metamaterials. All theoretical results are also validated through detailed finite element simulations. Selected metamaterials are additively fabricated from polymers using two-photon lithography and from stainless steel using selective laser melting. Static experiments are performed to confirm the theoretical modulus and yield stress estimates for uniaxial tension, compression and shear. Furthermore, dynamic experiments are performed on a Split Hopkinson Pressure Bar (SHPB) system to determine the effect of strain rate on the specific energy absorption response of mechanical metamaterials of 20% relative density.

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References