World Academy of Science, Engineering and Technology
International Journal of Mechanical and Materials Engineering
Vol:10, No:07, 2016

Effects of Hierarchy on Poisson’s Ratio and Phononic Bandgaps of Two-Dimensional Honeycomb Structures

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Abstract : As a traditional cellular structure, hexagonal honeycombs are known for their high strength-to-weight ratio. Here, we introduce a class of fractal-appearing hierarchical metamaterials by replacing the vertices of the original non-hierarchical hexagonal grid with smaller hexagons and iterating this process to achieve higher levels of hierarchy. It has been recently shown that the isotropic in-plane Young's modulus of this hierarchical structure at small deformations becomes 25 times greater than its regular counterpart with the same mass. At large deformations, we find that hierarchy-dependent elastic buckling introduced at relatively early stages of deformation decreases the value of Poisson's ratio as the structure is compressed uniaxially leading to auxeticity (i.e., negative Poisson's ratio) in subsequent stages of deformation. We also show that the topological hierarchical architecture and instability-induced pattern transformations of the structure under compression can be effectively used to tune the propagation of elastic waves within the structure. We find that the hierarchy tends to shift the existing phononic bandgaps (defined as frequency ranges of strong wave attenuation) to lower frequencies while opening up new bandgaps. Deformation is also demonstrated as another mechanism for opening more bandgaps in hierarchical structures. The results provide new insights into the role of structural organization and hierarchy in regulating mechanical properties of materials at both the static and dynamic regimes.

Keywords : cellular structures, honeycombs, hierarchical structures, metamaterials, multifunctional structures, phononic crystals, auxetic structures
Conference Title : ICCEM 2016 : International Conference on Computational and Experimental Mechanics
Conference Location : Istanbul, Türkiye
Conference Dates : July 21-22, 2016