Topology optimization for cellular composite compliant mechanisms with auxetic metamaterials by level sets

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Abstract

Metamaterials are artificially designed composites engineered to have unusual properties that are difficult to find in nature. They are usually characterized by assemblies of a number of periodic microstructures fashioned with conventional materials, such as metals or plastics. Hence, metamaterials normally gain unusual properties from their microstructures rather than from their material composition. Auxetic metamaterials are a special class of elastic materials that exhibit negative Poisson's ratio (NPR). NPR materials exhibit counter-intuitive elastic properties: expanding laterally when stretched, and contracting laterally when compressed. This paper will develop a new topology optimization method for the generation of novel compliant mechanisms using auxetic metamaterials. Compliant mechanisms are a new family of flexural mechanisms transferring force and displacement from input port(s) to output port(s) through elastic deformation of a piece pf monolithic material or jointless structure. Compared to the conventional rigid body mechanisms, the compliant mechanism offers the unique benefits such as no joints, no friction and no need of assembly and lubrication, due to the feature of single-piece monolithic structure.

Firstly, a new hierarchical multi-scale formulation is developed to account for the concurrent design of both the auxetic microstructure and the hosting compliant macrostructure. Secondly, the auxetic microstructures underpinning the macro flexible composite are topologically designed subject to boundary and loading conditions of the macrostructure. Finally, a level set method is applied to topologically optimize the representative microstructure, while the numerical homogenization method to evaluate the effective properties of the microstructures. Two typical numerical examples are used to demonstrate the effectiveness of the proposed method for the design of compliant mechanisms or monolithic flexural structure, using a new kind of artificial cellular composites periodically pared with auxetic metamaterials.

Keywords: Complaint mechanisms; Topology optimization; Auxetic metamaterials; Level set method; Cellular composites.