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Material symmetry phase transitions in three-dimensional tensegrity metamaterials

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Abstract

Prestressing the cables of tensegrity-based metamaterials is a widespread practice for enhancing their stability and mechanical properties. We choose a recently developed three-dimensional tensegrity lattice [1] and investigate material symmetry phase transitions induced by varying cable prestresses. We study several combinations of prestress cases and a vast regime of prestress values for each case. In each prestress scenario, we compute the effective elasticity tensor through a homogenization scheme. We study the material symmetries of the lattice by examining the eigenspaces of the homogenized elasticity tensor. We demonstrate material symmetry breaking and phase transitions, occurring solely due to cable prestressing. We observe several phase transitions including *cubic to tetragonal*, *tetragonal to orthotropic*, and vice-versa. We also compare phase transitions in finite and infinite lattices, showing that while certain prestress conditions lead to orthotropic symmetry in the finite lattices, they result in tetragonal symmetry for the infinite case. This discrepancy in symmetries of the finite and infinite lattices is due to periodic boundary conditions and the non-symorphic nature of the tensegrity lattice. Consequently, unlike many crystalline materials where increasing the size of the material is known to lead to symmetry reduction [2], we find a class of metamaterials where the infinite lattice exhibits a higher symmetry than the finite one.

Keywords: Tensegrity metamaterial, Material symmetry, Homogenization, Non-symorphic lattice, Size effect, Anisotropic elasticity

1. Introduction

The term tensegrity, originally introduced by Fuller [3], refers to a class of structures composed of cables and bars, in an arrangement such that tensile members (cables) belong to a continuous network, while compression members (bars) are either disconnected from each other or belong to isolated compression clusters [4]. Tensegrity structures exhibit strong geometric nonlinearities and are usually designed through form-finding processes [5, 6, 7, 8, 9, 10, 11]. They have been applied to a wide variety of problems, ranging

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