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Tunable Wave Propagation in Mechanical Metamaterials Made of Triangulated Cylindrical Origami

Abstract for NOLTA 2016

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We study unique wave propagation in origami-based mechanical metamterials composed of foldable origami structures, specifically Triangulated Cylindrical Origami (TCO). The TCO can be observed as a buckling pattern of a thin walled cylinder, and it can support both axial and rotational motions which can be strongly coupled with each other. To analyze wave dynamics of the TCO-based structures, we first model the TCO as a simplified 2 degree of freedom structure, by removing all facets and replacing crease lines by linear spring elements. Based on this simplified TCO unit, its static mechanical properties (e.g., force-displacement relationship and total potential energy) are examined. These mechanical properties can be controlled by altering the initial geometrical configurations of the TCO, such as height and rotational angle. In addition to the tunability of the constitutive properties, the TCO exhibits bistable behavior due to geometric nonlinearity. We verify this unique behavior experimentally by fabricating a prototype of the simplified TCO unit cell. By using the simplified TCO unit cell as a building block, we then design the TCO-based mechanical metamaterials in which multiple unit cells stacked vertically. We analyze wave propagation in this one-dimensional chain of the TCO unit cells with the focus on the coupling of axial and rotational motions. Under compressive impact, the TCO-based system exhibits unique wave dynamics such as the formation of rarefaction waves. Also, if the system consists of two distinctive TCO unit cells stacked in an alternating way, we observe formation of frequency band structures. Based on these unique characteristics, the TCO-based mechanical metamaterials have great potential for engineering applications, for example as mechanical wave filters and impact absorbers.