Impacting metamaterials : the threshold for wave propagation in holey columns

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Abstract

We report on the mechanical response of columns containing a periodic array of holes subject to impact loading. These holey columns are prototypical examples of mechanical metamaterials which have applications in sports engineering and as crumple zones ; here, the presence of holes render auxetic properties to the structure. When compressed slowly holey columns buckle locally beyond a compressive strain, and pattern switching (from circular holes to orthogonal ellipses) occurs everywhere at the same time. However, many applications involve dynamic loading. We observe that impact induces a compressive wave that buckles the ligaments surrounding a hole, nucleating a sequential pattern switching process, which ultimately leads to sequential self-contact of holes. Our focus is the threshold that separates a quasi-static and dynamic response to loading. We identify the critical impact velocity above which the compression can no longer be considered quasistatic and show that it depends on system size. Finally, we investigate the speed of buckling and self-contact waves, and their dependence on the impact velocity.

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