Quasi-crystalline Structural Composites: higher order symmetries and vibration localization

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Abstract

Periodic configurations have dominated the design of phononic and elastic-acoustic metamaterial structures for the past decades. Unlike periodic crystals, quasicrystals lack translational symmetry but are unrestricted in rotational symmetry. This provides the opportunity to investigate novel classes of quasicrystal inspired elastic composites whose mechanical static and dynamic properties are largely unexplored. This presentation illustrates the performance of continuous elastic quasicrystals composites, here denoted as *quasiperiodic* (QP) composites, characterized by different rotational symmetry orders which is directly enforced through a design procedure in reciprocal space. Static mechanical properties are investigated as a function of symmetry order and filling fraction. Results indicate that higher order symmetries, such as 8-, 10- and 14-fold, lead to equivalent stiffness characteristics that interpolate those of the constituent materials while maintaining high levels of isotropy for all filling fractions. Thus, QP composites exhibit more uniform strain energy distributions when compared to periodic 4-fold and 6-fold symmetric configurations. Similarly, nearly-isotropic wave propagation is observed over a broader range of frequencies. The spectral dynamic properties are also investigated by enforcing rotational symmetry constraints in a wedge-type unit cell, which allows for the estimation of bandgaps, whose presence is confirmed in frequency response computations. Wave directionality and bandgaps are also estimated through parallel studies conducted on plate structures characterized by QP patterns of surface stubs. These experiments show clear bandgaps, illustrate how wave fronts reflect the rotational symmetry of the domains, and demonstrate that higher order geometries lead to isotropic propagation over a broader range of frequencies. The investigations presented herein open avenues for the general exploration of the properties of quasiperiodic media, with potentials for novel architectured material designs that expand the opportunities provided by periodic media.

Massimo Ruzzene is the Slade Professor of Mechanical Engineering and holds a joint appointment in the Smead Aerospace Engineering Sciences Department of CU Boulder. M. Ruzzene currently serves as the Associate Dean for Research of the College of Engineering and Applied Science. He joined CU in the summer of 2019, after serving as the Pratt and Whitney Professor in the Schools of Aerospace and Mechanical Engineering at Georgia Institute of Technology. M. Ruzzene received a PhD in Mechanical Engineering from the Politecnico di Torino (Italy) in 1999. He is author of 2 books, more than 180 journal papers and 250 conference papers. He has participated as a PI or co-PI in various research projects funded by the Air Force Office of Scientific Research (AFOSR), the Army Research Office (ARO), the Office of Naval Research (ONR), NASA, the US Army, US Navy, DARPA, the National Science Foundation (NSF), as well as companies such as Boeing, Eurocopter, Raytheon, Corning and TRW. Most of his current and past research work has focused on solid mechanics, structural dynamics and wave propagation with application to structural health monitoring, metamaterials, and vibration and noise control. M. Ruzzene is a Fellow of ASME and SES, an Associate Fellow of AIAA, and a member of AHS, and ASA. He served as Program Director for the Dynamics, Control and System Diagnostics Program of CMMI at the National Science Foundation between 2014 and 2016.