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Mechanical Engineering Seminar Series

Metadamping in elastic metamaterials: Dissipation engineering by intrinsic resonances

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ME Seminar Zoom link (QR Code below)

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Abstract

In civil, mechanical, and aerospace engineering, structural dynamics is viewed as a discipline concerned with the analysis and characterization of the vibratory response of structures. Key elements of the response are the amplitude, phase, and damping ratio, which are quantities that vary with the excitation frequency. In this work, we extend the notion of damping engineering in structural dynamics to the realm of materials engineering by intrinsically introducing locally resonating substructures within, or attached to, the material domain itself−which is viewed as an extended medium without defined external boundaries. This essentially yields a locally resonant elastic metamaterial, except here it is viewed from the perspective of its dissipation characteristics rather than its subwavelength effective properties or band gaps, as widely done in the literature.

We provide a theory, validated by experiments, for substructurally synthesizing the dissipation under the conditions of free-wave motion, i.e., waves not constrained to a prescribed driving frequency. We use an extended elastic beam with attached pillars as an example of a metamaterial. When compared to an identical infinite beam with no attached substructures, we show that within certain frequency ranges the metamaterial exhibits either enhanced or reduced dissipation−which we refer to as positive and negative *metadamping*, respectively. These regimes are rigorously identified and characterized using the metamaterial's band structure and wavenumber-dependent dissipation diagram, thus opening up a new paradigm for dissipation engineering without addition or subtraction of damped material. This concept impacts applications that require a combination of high stiffness and high damping or, conversely, applications that benefit from a reduction in loss without the need to change the backbone constituent material.

Bio

Mahmoud I. Hussein is the Alvah and Harriet Hovlid Professor in the Smead Department of Aerospace Engineering Sciences, and has a courtesy and affiliate faculty appointments in the Departments of Physics and Applied Mathematics, respectively, at the University of Colorado Boulder. He is the director of the Pre-Engineering Program at the College of Engineering and Applied Science, and the director of the Phononics Laboratory. He received a BS degree from the American University in Cairo and MS degrees from Imperial College, London and the University of Michigan–Ann Arbor. He earned his PhD from the University of Michigan in 2004, and completed postdoctoral research at the University of Cambridge from 2005-2007. Dr. Hussein received a DARPA Young Faculty Award in 2011, an NSF CAREER award in 2013, and in 2017 was honored with a Provost's Faculty Achievement Award for Tenured Faculty at CU Boulder. He is a Fellow of ASME. In addition, he is the founding vice president of the International Phononics Society and has co-established the Phononics 20xx conference series which is widely viewed as the world's premier event in the emerging field of phononics. Dr. Hussein's research interests lie broadly in the fields of phononics and nonlinear wave propagation.

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