

PROCEEDINGS

Load-Characteristic-Adaptive Impact-Resistant Mechanical Metamaterials

Wei-Jing Wang¹ and Li Ma^{1,*}

¹Center for Composite Materials, Harbin Institute of Technology, Harbin, 150080, China

*Corresponding Author: Li Ma. Email: mali@hit.edu.cn

ABSTRACT

In impact protection and intelligent-response scenarios, loading conditions often involve varying strain rates and energy inputs, which place increasing demands on lightweight design, efficient energy absorption, and adaptive mechanical response. Conventional cellular structures are prone to instability and noticeable lateral deformation under large strains, while energy absorption mainly depends on irreversible plastic deformation, leading to limited reusability and insufficient adaptability to different loading characteristics. In this context, a family of three-dimensional zero Poisson's ratio metamaterials was designed, fabricated, and characterized. Shear-thickening gel was further introduced as a functional filler to construct a material-structure synergistic energy-absorbing system. Quasi-static and impact tests were performed to evaluate deformation behavior, dynamic response, and reusability under different strain-rate loading conditions. The unfilled metamaterial exhibited an ordered progressive collapse mode and maintained a stable near-zero Poisson's ratio effect even under large deformation. Compared with the unfilled counterpart, the filled metamaterial showed significantly improved plateau stress, specific energy absorption, and rebound strain. Increasing impact velocity further enhanced mechanical response and energy absorption capability, revealing a load-characteristic-adaptive synergistic mechanism governed by structural response and strain-rate-dependent material behavior. Repeated impact tests also demonstrated favorable reusability, with both unfilled and filled metamaterials retaining a high proportion of the initial specific energy absorption after repeated impacts. These results demonstrate the feasibility of integrating zero Poisson's ratio architectures with functional fillers for load-characteristic-adaptive impact-resistant mechanical metamaterials.

KEYWORDS

Impact-resistant mechanical metamaterials; zero Poisson's ratio; shear-thickening gel; energy absorption

Funding Statement: This work was supported by the Fundamental Research Project of the “Dengfeng Program” for Doctoral Students, School of Astronautics, Harbin Institute of Technology under Grant No. HITSADF2026009 to W.J. Wang, and the National Natural Science Foundation of China under Grant Nos. 12072092 and 12472128 to L. Ma. Sponsor websites: School of Astronautics, Harbin Institute of Technology, <https://sa.hit.edu.cn/>; National Natural Science Foundation of China, <https://www.nsfc.gov.cn/>.

Conflicts of Interest: The authors declare no conflicts of interest to report regarding the present study.



Copyright © 2026 The Author(s). Published by Tech Science Press.

This work is licensed under a Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.