Cyclic elastoplastic shakedown behavior of an auxetic metamaterial

Shen Wang*†[1], Michael Peigney[2], and Natasha Vermaak[1]

[1]Lehigh University [Bethlehem] – United States
[2]Université Gustave Eiffel – CNRS : UMR8205, ENPC, ENPC, CNRS – France

Abstract

Auxetic structures exhibiting effective negative Poisson's ratio behavior have shown promising energy absorption capabilities in applications subject to cyclic loadings in the elastic domain. However their cyclic elastoplastic behaviors, and shakedown response in particular, have not been fully understood. Wang et al. (1) predicted the maximum loading capacity of a variety of auxetic tubular lattice structures using the proposed direct numerical shakedown method. The study was entirely computational and did not discussed the relationship between the structure auxeticity and their shakedown behaviors. The present work (2) focuses on auxetic metamaterial structures achieved by regular perforations in Aluminum sheets (3). These auxetic sheets are subjected to asymmetric cyclic uniaxial tensile loads at room temperature to elicit elastic and resilient elastoplastic behaviors without compressive buckling. The study aims to determine the safe elastoplastic shakedown limit of the perforated auxetic aluminum sheet structures (AA5083-TO) with fixed void fraction (16.4%). The motivation is that shakedown-based designs can be used to expand the feasible design space under cyclic loading conditions compared to conventional yield-limited designs. Experimental, numerical, and theoretical results are used to elucidates interactions between auxeticity and maximum shakedown loading capacity. In particular, a non-monotonic relationship between the shakedown multiplier and auxeticity was identified. Furthermore, it was found that shakedown occurs at stress levels 2-4 times the elastic limit of the structure for a fixed allowable equivalent strain level (at approximately 3%). The analytical model is used to explore the underlying mechanisms and to propose a simple structural index to aide in optimal design.

KEYWORDS: Shakedown; Auxetic metamaterials; Cyclic plasticity

(1) Wang, L., Chen, M., Chen, G., Luo, T. & Liu, F. Loading Capacity Prediction of the Auxetic Tubular Lattice Structures by Multiscale Shakedown Analysis. Compos. Struct. 314, 116938 (2023).

(2) Wang, S., Peigney, M. & Vermaak, N. On the cyclic elastoplastic shakedown behavior of an auxetic metamaterial : An experimental , numerical , and analytical study. J. Mech. Phys. Solids 192, (2024).

(3) Taylor, M. et al. Low porosity metallic periodic structures with negative poisson's ratio. Adv. Mater. 26, 2365–2370 (2014).

*Speaker

†Corresponding author: shw218@lehigh.edu