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# Numerically Informed Neural Networks for Damage Detection in TPMS Lattice Structures via Acoustic Resonance Testing

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Lattice structures have attracted increasing interest due to their unique mechanical properties, which are difficult to achieve with conventional materials. Despite their promising potential, damage identification in these complex structures remains challenging, while damage localization and severity quantification are still insufficiently explored.

This study aims to develop a neural-network-based approach for damage detection, localization, and quantification using variations in the natural frequencies of lattice specimens obtained through acoustic resonance testing. To this end, a numerically generated dataset, further expanded through artificial data augmentation incorporating physical variability, was used to train and validate the model.

The proposed approach was then assessed using an experimental dataset comprising specimens with known damage locations and damage extents induced by fatigue cycles associated with stiffness degradation. A dedicated algorithm was developed to correlate the numerical and experimental datasets.

The developed neural network successfully identified the presence and location of damage in all specimens of the experimental dataset. In contrast, damage extent estimation proved more challenging, showing reliable accuracy only for stiffness reductions above 5%.

These findings indicate that combining acoustic resonance testing with neural networks is a viable strategy for damage assessment in lattice structures, providing reliable detection and localization capabilities while paving the way for improved damage quantification.

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