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Geometrically Nonlinear Analytical Model harnessing Secondary Bifurcations in MEX-Manufactured Stayed Lattice Cells

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Abstract

Lattice structures are widely recognized for offering a remarkable strength-to-weight ratio. However, their slender members remain highly sensitive to elastic buckling at low relative densities. To overcome this limitation, a novel lightweight and high-performance collinear stayed lattice structure has been developed and fabricated using material extrusion (MEX) additive manufacturing (AM) technology [1,2]. The unit cell (UC) of this structure consists of a vertical column, orthogonal cross arm, and restraining diagonal stays. The group's methodological three-tone make–break–simulate is iteratively applied in order to examine buckling and post-buckling behaviour of UCs under uniaxial compression. In the make phase, the restraining stays are fabricated in air without support using MEX AM, enabling the intended mechanical design concept. In the break phase, uniaxial compression tests combined with digital image correlation (DIC) are conducted to observe the buckling behaviour in detail. The secondary bifurcation behaviour was observed in the experiments. In the simulate phase, a geometrically nonlinear analytical model based on the general theory of elastic stability [3] is implemented using the Python-based module PyFurc [4]. The restraining effect of the stays is simulated through extensional springs. A novel approach will be presented which introduces nonlinear springs providing the ability to capture the experimentally observed secondary bifurcation

behaviour. This offers new modelling possibilities compared to the previous model with linear springs [5], which merely simulated individual buckling modes. The model is subsequently validated through experimental DIC measurements, confirming the accuracy of the simulation. With the newly introduced nonlinear-spring approach, the secondary bifurcation can thus be identified explicitly and analyzed in detail. This new analytical model simulates the post-buckling behaviour accurately and offers the possibility for comprehensive parametric studies. Using the aforementioned iterative methodological three-tone, a set of parameters is subsequently explored and optimized, enabling the development of improved UCs [2]. Different types of UCs provide a broad foundation for designing 2D and 3D lattices, enabling the tuning of local behaviour at specific locations within the global lattice structure.

Keywords:

Lattice structures MEX AM Analytical modelling Non-linear spring Parameter study

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