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Bio-inspired Cellular Nanocomposite Shells: Stability Analysis

The pressing global issues of climate change, sustainability, and energy efficiencyspark an urgent demand for resilient lightweight structures. Consequently, porous cellular materials have emerged as a promising category of lightweight materials capable of concurrently meeting various requirements, ranging from structural stiffness to thermal insulation. While the majority of metal foam studies focus on random porosity, recent research actively pursues economic multi-functionality through precise control of pore size and density. This approach draws inspiration from bio-inspired functionally graded materials, which prioritises gradual transitions, observed in the intriguing instances of squid beaks and varying bone porosity. Consequently, this paradigm has given rise to novel continuously graded porous (CGP) metal foam structures. Building upon these concepts, this paper introduces a innovative numerical model to analyse the buckling behaviour of bio-inspired CGP nanocomposite cylindrical shells. An effective constitutive law for an elastic isotropic metal matrix containing distributed elastic carbon-nanotubes (CNTs) is estimated, considering CNTs agglomeration through an Eshelby-Mori-Tanaka (EMT) approach. Unlike conventional methods, Euler-Bernoulli beams model stiffeners within CGP shells for a more realistic representation of stiffener effects. Equilibrium equations based on Reddy's higher-order shell theory are derived using the Euler equation and stability equations are obtained through the variational method. The stability equations were solved employing the generalised differential quadrature and Levy techniques. The intricate interplay between CNTs and porosity distributions significantly affects the stability behaviour of CGP shells. These findings offer valuable insights for designing closed-cell cellular stiffened shells with optimal porosity to improve buckling stability.

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Dr Behnam Sobhani is a Lecturer (Assistant Professor) in Mechanical Engineering at Teesside University, United Kingdom, where he brings extensive expertise in computational mechanics of lightweight and low carbon materials in multiphysics environments. Before joining Teesside University, Dr Sobhani conducted groundbreaking research as a postdoctoral researcher/Group Leader at Technical University of Darmstadt, Germany, focusing on developing micromechanical modelling of lightweight nanocomposite/composite structures, along with his work in thermo-mechanical phase-field modelling for coupled fracture and phase transformation in polycrystalline microstructures. Notably, his academic journey included prestigious research roles at USP and UFRJ, Brazil, where he was awarded the prestigious postdoctoral fellowship by FAPESP. During this time, he has focused on structural integrity and micromechanics of composite structures. Dr Sobhani holds a Ph.D. in Electro-Mechanical Engineering from Ghent University (UGent), Belgium. In his pioneering thesis conducted at the esteemed Soete Laboratory, Department of Mechanical Construction and Production, he proposed novel methodologies for the structural analysis of composite/nanocomposite structures.

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