A089
Geometrically Nonlinear Analysis of Nanoshells Using Strain Gradient Theory and Hierarchical Hermite Finite Elements

Cheng Angelo Yan (1); Nicholas Fantuzzi (1); Riccardo Vescovini (2); Raimondo Luciano (3)

(1) DICAM Department, University of Bologna (Italy); (2) DAER Department, Politecnico di Milano (Italy); (3) Engineering Department, Parthenope University of Naples (Italy)

The nonlinear behaviour of shell structures is highly sensitive to geometry, loading conditions, and initial imperfections. At the micro- and nano-scale, these complexities become even more pronounced due to the emergence of size-dependent effects that significantly influence the mechanical response. Accurately capturing the coupled influence of geometric nonlinearity and nonlocality therefore remains a major challenge, requiring advanced computational formulations capable of addressing both phenomena simultaneously. To this end, the present work proposes a novel nonlinear finite element framework for nanoshell analysis that incorporates both geometric nonlinearities and nonlocal scale effects. The formulation is developed within the Kirchhoff–Love shell theory, while geometric nonlinearities are introduced through the von Kármán kinematic assumptions. Size dependency is modelled using a second-order strain gradient constitutive theory, resulting in a system of sixth-order nonlinear partial differential equations. The governing equations are solved through a combined finite element and perturbation-based strategy. The shell generalized displacements are approximated using a novel hierarchical Hermite polynomial interpolation that satisfies the high continuity requirements imposed by the strain gradient model. The resulting finite element unknowns are then expanded through an asymptotic perturbation scheme, yielding a semi-analytical solution of the nonlinear problem. This approach enables an efficient and accurate prediction of post-buckling behaviour and nonlinear vibration responses in nanoshell structures. Numerical investigations demonstrate the effectiveness of the proposed framework in capturing the complex interaction between nonlinearity and nonlocality. The results reveal significant deviations from classical shell models and emphasise the critical importance of incorporating size-dependent effects in the nonlinear analysis of nanoscale shell structures.