Nonlinear Analysis of Functionally Graded Materials Using Linear and Quadratic Solid–Shell Finite Elements

Nabeel Younas*†[1]

[1]Engineering and Technology Institute Groningen (ENTEG), Faculty of Science Engineering, University of Groningen-Nijenborgh 4, 9747 AG Groningen – Netherlands

Abstract

This work presents the development and evaluation of prismatic and hexahedral solid–shell (SHB) finite elements, formulated in both linear and quadratic versions, for the nonlinear geometric analysis of thin structures composed of functionally graded materials (FGMs). These elements are constructed within a fully three-dimensional framework, where only displacement degrees of freedom are employed. To address common numerical challenges, a combination of in-plane reduced integration and the assumed-strain method is utilized, effectively countering locking issues. The through-thickness material variation in FGMs is represented by strategically placing integration points across the element's thickness, enabling precise modeling of gradation effects. The SHB elements are integrated with a material model that captures the functional gradation of mechanical properties, assuming a continuous variation of Young's modulus along the thickness according to a specified volume fraction distribution. Implementation is carried out within the ABAQUS/Standard finite element platform under quasi-static conditions, accommodating large deformation scenarios. A series of nonlinear benchmark problems, including those frequently cited in the literature, are used to validate the performance of these elements. The results highlight the accuracy and computational efficiency of both linear and quadratic SHB elements in simulating the complex behavior of thin FGM plates, demonstrating their suitability for advanced engineering applications.

*Speaker

†Corresponding author: n.younas@rug.nl