Solution bound and nearly exact solution to 3D nonlinear solid mechanics problems using S-FEM

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Abstract

In this work, 3D smoothed finite element method (S-FEM) is developed with Ogden's model for hyperelastic material modeling to solve 3D nonlinear large deformation problems. Node-based and face-based S-FEM using four-noded tetrahedral element(NS-FEM-T4 and FS-FEM-T4) are adopted to find solution bounds. The lower bound strain energy solutions are obtained using FEM-T4 and FS-FEM-T4, while the upper bound solutions are obtained using NS-FEM-T4. The combined α S-FEM-T4 are used to find nearly exact solution to nonlinear solids mechanics problems through adjusting factor α that control the combination. This is achieved using the property that a successive change of scaling factor α can make the model transform from "over-stiff" to "over-soft". Hyperelastic modeling of Mooney-Rivlin and Ogden material are used to simulate nonlinear problems using S-FEM. Numerical examples reveal that S-FEM-T4 is effective method for obtaining solution bounds together with the standard FEM, and the FS-FEM-T4 and NS-FEM-T4 are robust with high accuracy and computational efficiency for complicated nonlinear problems.

Keywords: Smoothed finite element method, Nonlinearity, FEM, Exact solution, Solution bound.