An optimal multiple smoothing scheme of selective cell-based smoothed finite element methods with 10-node tetrahedral elements for large deformation of nearly incompressible solids

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Abstract

The smoothed finite element methods (S-FEM) [1] has attracted attention as a new finite element formulation that can obtain highly accurate solutions even with 4-node tetrahedron meshes. The edge-based smoothed finite element method (ES-FEM-T4) is particularly effective in the solid analysis because it can avoid the shear locking issue. However, since ES-FEM-T4 can not avoid the volumetric locking and pressure checkerboarding issues, improvement researches of S-FEMs for large deformation of nearly incompressible materials are still actively continued [2, 3, 4, 5, 6, 7, 8, 9, 10]. A few years ago, we proposed a state-of-the-art S-FEM that combines ES-FEM-T4 and NS-FEM-T4 cyclic smoothing using F-bar method (F-barES-FEM-T4 [6]), and resolved the volumetric locking and pressure checkerboarding issues in S-FEM-T4. Nonetheless, there still remains two issues in F-barES-FEM-T4: a certain level of increase in computational cost and difficulty of implementation into standard FEM codes, which inhibit the widespread use of F-barES-FEM-T4. We then proposed a conceptual method, SelectiveCS-FEM-T10 [10], as a novel tetrahedral cell-based S-FEM (CS-FEM) using a 10-node tetrahedral (T10) element. In SelectiveCS-FEM-T10, a T10 element is divided into T4 subelements, cyclic (or multiple) smoothing among T4 subelements is performed for each deviatoric and hydrostatic stress part, and the two stress parts are combined with the selevtive method. Since SelectiveCS-FEM-T10 is a kind of CS-FEM, its computational cost is the same as that of the standard T10 element and it can be implemented into the standard FEM code. A wide variety of schemes can be applied to the multiple smoothing, the investigation for optimal multiple smoothing schemes is required to be addressed. In this research, we present a formulation with the best accuracy and stability among the various schemes tested and discuss the reason why the scheme is superior. We also show the analysis results using the optimal scheme and verify the effectiveness of the proposed method through comparison with the conventional tetrahedral FEMs.

Keywords: Cell-based smoothed finite element method, 10-node tetrahedral element, Large deformation, Volumetric locking, Pressure checkerboarding, Reaction force oscillation.

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