Sefea^{tm} (Strain Enriched Finite Element Analysis) theory, benchmarks and applications

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Sefea (Strain Enriched Finite Element Analysis) research focuses on solving problems in the increasingly realistic CAE simulations performed daily by CAD users with minimum to intermediate FEM know-how, as well as by experienced analysts drawn into the convenient solid modeling technology. Traditionally, in such CAE environments, only the tetrahedral element generation is robust and reliable enough for general geometry. The low-order 4-noded tetrahedron (TET4) is robust enough to solve general problems but is considered too stiff; only the 2nd-order 10-node tetrahedron (TET10) is accurate enough for general analysis, although it still exhibits deficiencies for general nonlinear dynamic problems.

In this paper, we present current Sefea basic theory and formulation for general finite element analysis with multi-physics extension. This method's novelty is inspired by the strain projection method [1]. Recognizing that the constant dilatational strain in TET4 is the culprit of locking, we incorporate the more accurate dilatational strain formulation from each TET4 corner node similar to those proposed in EFGM or node integration method [2], while keeping the deviatoric strain from FEM. Effectively, Sefea "enriches" the TET4 constant strain into an equivalent tri-linear strain while keeping the TET4 reliable shearing behavior without using additional nodes.

Using such enrichment methods, Sefea delivers a new low-order element family in the same robust FEM tool that has been used for more than a half century. It provides the accuracy of higher order elements without solving additional equations.

We present several benchmark results in 2D, 3D and shell problems to demonstrate Sefea numerical superiority in daily CAE analysis. A unified Sefea multiphysic extension for solving thermal diffusion equation, incompressible Navier-Stokes equation [3] and electromagnetic Maxwell equation are discussed, with examples demonstrating the Sefea TET4/TRI3 accuracy and applicability for general CAE multiphysic applications.

References

[1] T.J.R Hughes, "Generalization of Selective Integration Procedures to Anisotropic and Nonlinear Media," IJNME 1980, 15, 1413-1418.

[2] J. Bonet, H. Marriott, O. Hassan, "An average nodal deformation gradient linear tetrahedral element for large strain explicit dynamic applications," CINME 2001, 17, 551-561.

[3] H.T. Lin, "A Conserving Optimal Least-Squares Finite Element Method for CFD Problems," World Congress on Computational Mechanics VII, 2006