Formulation of new quadratic solid–shell elements and their evaluation on popular benchmark problems

Vuong-Dieu TRINH[1], Farid ABED-MERAIM[1], Alain COMBESCURE[2]

(1) LPMM FRE CNRS 3236, Arts et Métiers ParisTech, 4 rue Augustin Fresnel, 57078 Metz
vuong-dieu.trinh@metz.ensam.fr, farid.abed-meraim@metz.ensam.fr
(2) LaMCoS UMR CNRS 5259, INSA-Lyon, 18, 20 rue des Sciences, 69621 Villeurbanne
alain.combescure@insa-lyon.fr

ABSTRACT

Introduction. Over the last decade, considerable progress has been made in the development of three-dimensional finite elements capable of modeling thin structures [1-12]. The coupling between solid and shell formulations has proven to be an interesting way to provide continuum finite element models that can be efficiently used for structural applications.

Methods. The current work proposes the formulation of two solid-shell elements based on a purely three-dimensional approach. These elements have numerous advantages for the analysis of various complex structural geometries that are common in many industrial applications. Their main advantage is to allow such complex structural shapes to be meshed without classical problems of connecting zones meshed with different element types (continuum and structural elements for instance). Another important benefit of solid-shell elements is the avoidance of tedious pure-shell element formulations needed for the complex treatment of large rotations. The two solid-shell elements developed are a 20-node and a 15-node element, respectively, with displacements as the only degrees of freedom. They also have a special direction called “the thickness”. Therefore, they can be used for the modeling of thin structures, while providing an accurate description of various through-thickness phenomena thanks to the use of a set of integration points in that direction. A reduced integration scheme has been introduced to prevent some locking phenomena and increase computational efficiency.

Results. To assess the effectiveness of the proposed solid-shell elements, a set of popular benchmark problems is investigated, involving linear as well as geometric nonlinear analyses. It is shown that these elements can support high aspect ratios, up to 500, and are especially efficient for elastoplastic bending behavior.

Conclusion. The various numerical experiments in linear and nonlinear situations reveal that these solid-shell elements perform really better than standard solid elements having similar properties in terms of geometry, interpolation and degrees of freedom.

References.

[1] Roehl, D, Ramm, E 1996.
[2] Domissy, E 1997.
[3] Cho, C, Park, HC, Lee, SW 1998.
[4] Lemosse, D 2000.
[5] Sze, KY, Yao, LQ 2000.
[6] Hauptmann, R, Doll, S, Harnau, M, Schweizerhof, K 2001.
[7] Vu-Quoc, L, Tan, XG 2003.
[8] Chen, YI, Wu, GY 2004.
[9] Kim, KD, Liu, GZ, Han, SC 2005.
[10] Alves de Sousa, RJ et al. 2006.
[11] Reese, S 2007.
[12] Abed-Meraim, F, Combescure, A 2009.