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A NEW REDUCED INTEGRATED SOLID-SHELL ELEMENT FOR SHEET METAL FORMING APPLICATIONS

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ABSTRACT

Solid-shell elements are being widely used in large scale computational mechanics. The principal reasons for their popularity are essentially because: they can reproduce better than shell elements the normal stress along the thickness direction, and thus are more suitable for sheet metal forming simulations with double sided contact; they have only translational degrees of freedom, which reduce the complexity that comes from shell formulations when nodal rotations are used; they are more appropriate for interface modelling with solid elements.

In the meanwhile, solid-shell elements have serious locking pathologies like Poisson's locking, volumetric locking, membrane and transverse shear locking which, for the case of transverse shear locking, is more pronounced when the ratio thickness to length approaches zero. Recently, Alves de Sousa et al. [2] proposed a solid-shell element with reduced in-plane integration and several integration points along thickness direction of the element. However, the solid-shell element of Alves de Sousa uses the Selective Reduced Integration (SRI) approach for the transverse shear strains and cannot pass the membrane and bending patch tests. The use of SRI for the transverse shear strains showed some instability on the element. Later, Cardoso et al. [2] solved these instabilities with the replacement of SRI method with ANS method and also with a new formulation for the hourglass membrane strains in order to pass the membrane patch test.

In this work, a new solid-shell element is developed for one single layer shell structures with reduced in-plane and multiple integration points along the thickness direction of the shell. The formulation consists of several combinations of well-known techniques to solve locking pathologies as is the case of the Enhanced Assumed Strain (EAS) method, the Assumed Natural Strain (ANS) method and also the reduced integration technique. In order to correct the rank deficiency of the element, physical stabilization of the zero energy modes is used together with B-bar approach in such a way that isochoric plastic deformations can be avoided.

The proposed element is implemented in the new version of MSC.Software packages MSC.Marc 2007 and MSC.Nastran Sol 400, passes the membrane and bending patch tests and performs remarkably well in large scale complex industrial problems involving contact and plasticity.

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