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M. Harnau, K. Schweizerhof
Universität Karlsruhe, Institut für Mechanik

2000

Institut für Mechanik
Kaiserstr. 12, Geb. 20.30
76128 Karlsruhe
Tel.: +49 (0) 721/ 608-2071
Fax: +49 (0) 721/ 608-7990
E-Mail: ifm@uni-karlsruhe.de
www.ifm.uni-karlsruhe.de

On Linear and Quadratic 'Solid-Shell' Elements with mixed approximations avoiding locking behavior

M. Harnau, K. Schweizerhof
Institut für Mechanik, Universität Karlsruhe, 76128 Karlsruhe, Germany

The well known Solid-Shell concept was originally developed as 'four-node type' resp. eight-node elements with trilinear shape functions [4], [5]. The same concept is now used to develop 'nine-node type' resp.eighteen-node elements with biquadratic-linear shape functions. Both are then investigated concerning their capabilities and limits for applications in the large deformation regime.

The major advantage of the 'nine-node type' elements with the biquadratic-linear shape functions is mainly that a much better geometrical approximation especially for curved shell structures becomes possible. This is shown with different numerical examples.

Besides the well known phenomena of shear, membrane and thickness locking, which are avoided by using the assumed strain concept [3] for the interpolation of the shear and membrane terms, and in addition using the enhanced assumed strain concept for the interpolation in thickness direction [2], two further locking problems, the well known incompressibility locking and the so-called 'trapezoidal' locking are investigated. A rather efficient possibility to resolve this problem is to use the so-called selective reduced integration for the volumetric parts of the stress tensor and the tangent moduli tensor, which is compared to results using the EAS-method.

The effect of so called trapezoidal locking is only found in curved structures, where the directors of the element edges are not vertical to the mid-layer. One method to resolve this problem is using an assumed strain interpolation of the normal strain in thickness direction as suggested in [1] where it was proposed to avoid artificial thickness straining.

Using these mixed methods to avoid locking effects leads to the problem that under some types of loading the trilinear elements as well as the biquadratic-linear elements become unstable, indicated by negative eigenvalues of the tangential stiffness matrix. Different procedures to resolve such problems are already suggested in the literature, however they appear not to be generally applicable.

References

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