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An automated and efficient implementation concept for shell elements with high computational performance in explicit time integration

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Abstract

An explicit time integration method that is suitable for very fast processes and highly nonlinear problems is the central difference scheme [1], often also called VERLET-algorithm [2]. Due to the necessity of very small time steps the element routine is called very often inside the algorithm. For lumped mass matrices the costly solution of coupled linear equations on global level is not necessary. But the time step size is constricted by a critical value that is given by the COURANT-criterion [3]. Consequently the central difference scheme is mostly attractive for highly dynamic problems where small time steps are required anyway. In addition it is preferably used for highly nonlinear problems where convergence with implicit algorithms is hard to achieve.

In this contribution the focus lies on an efficient implementation concept that enables the generation of different types of finite elements with high computational performance. The implementation concept is based on the application of the symbolic programming tool ACEGEN [4, 5, 6, 7], an extension to the computer algebra software MATHEMATICA, which allows a combination of symbolic operations together with the automatic generation of highly efficient program code.

The adaptability of the concept is demonstrated with the solid-shell finite element concept and with an axisymmetric volume shell element. The presented shell elements including standard (=full) numerical integration in combination with different approaches in order to reduce artificial stiffness effects are implemented into the in-house Finite Element code FEAP-MEKA [8].

For analysing thin-walled structures it is adequate to use shell elements that are able to capture thickness effects. For poor aspect ratios of the elements, e.g. for very small thicknesses, the so called geometric locking effect appears that is removed with the method of '*Assumed Natural Strains*' (ANS), where the strains are evaluated at specific sampling points and interpolated. The volumetric locking effect that affects simulations near the incompressible limit is reduced with the '*Enhanced Assumed Strain*' (EAS) method. An axisymmetric element formulation can be obtained by assembling axisymmetric constraints on a simple 3D-solid shell element. The implementation of further element procedures like the EAS and ANS method is performed by also applying symbolic programming.

The specifics of the implementation concept are discussed and the efficiency and functionality of the element formulations are presented on numerical examples for transient dynamics including large deformations.

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