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SELECTIVE MASS SCALING FOR SOLID-SHELL ELEMENTS IN EXPLICIT DYNAMICS ANALYSES

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In view of the current trends in the development of computing architectures, evolving in the direction of finer and finer parallelization, often with the aid of co-processors or graphics card units with limited availability of on-board memory, explicit dynamics methods for the solution of highly nonlinear structural problems are gaining increasing attention. As it is well known, however, explicit methods are only conditionally stable and may require extremely small time steps, approximately linearly decreasing in size with the smallest element geometrical dimension in the mesh. The problem is particularly evident when solid-shell elements are employed, since they present a thickness which can be a small fraction of the element in-plane dimensions. Solid-shell elements are becoming increasingly popular as they make use of displacement degrees of freedom only and can naturally incorporate complex three-dimensional material behaviors, even though their use in explicit dynamics has been seldom considered, in view of this limitation on the critical time-step.

A common way to increase the critical time step size is to scale the model inertia, while keeping the stiffness constant. In doing this, the objective is to reduce the high frequency modes only, while leaving the lower ones unaltered. In particular, in inertia dominated problems, it is essential to leave the inertia associated to translational rigid body modes unaltered. To obtain this, several selective mass scaling techniques have been proposed in the literature (see e.g. [1, 2, 3, 4]). The common drawback of these approaches is that the resulting selectively scaled mass matrix is no more diagonal, even when starting from a lumped mass matrix, thus requiring the solution of a linear system for the acceleration computation at each time step.

A different approach, specifically conceived for solid-shell elements and inspired to the scaling of rotational inertia usually adopted in classical shell elements, has been proposed in [5]. The method is based on a linear transformation of degrees of freedom and has the advantage that it can be used keeping the diagonal structure of the mass matrix. An analytical estimate of the maximum eigenfrequency for the simple case of parallelepiped elements was also provided. An empirical strategy for the definition of the optimal selective scaling factor was proposed in [6], still restricted, however, to parallelepiped elements.

The case of arbitrarily distorted solid-shell elements is discussed here, together with a more rigorous strategy for the definition of the optimal scaling factor. Following the approach proposed in [7], an effective procedure for the estimation of the critical time step for the scaled distorted element is proposed, based on a one-Gauss point integration. It is also shown how the selective mass scaling can be equivalently interpreted as a geometric scaling in the thickness direction, thus providing a natural definition of the optimal scaling parameter: the maximum value of the scaling factor is the one which makes the current element thickness of the same magnitude of the average in-plane dimensions. Numerical tests allow to assess the accuracy and effectiveness of the proposed strategy.

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