High order solid elements for thin-walled structures with applications to linear and non-linear structural analysis

As an alternative to the well-known and widely used dimensionally reduced formulations for an approximation of thin-walled structures we will investigate in this paper the feasibility of strictly three-dimensional models, using high order elements being coupled to a precise geometric description of the structure. As a key issue the p-version of the FEM is used, offering a consistent and accurate way to implement solid elements having a very large aspect ratio (up to a few hundred) and to represent much more general shapes of element surfaces than those available in the usual isoparametric approach. A transition from thin- to thick-walled constructions is thus possible without the necessity to couple models of differing dimensions and without imposing any restrictions on the (threedimensional) kinematics of the structure. We will first focus our discussion especially on the question of an efficient implementation of these elements, i.e. on an advantageous choice of anisotropic higher order Ansatz spaces and on coupling of the finite element analysis to a geometric model. One obtains an efficient code being consistent to the threedimensional theory of elasticity by construction. These general principles will then be extended to non-linear problems. We will demonstrate our results in several numerical examples ranging from a strictly three-dimensional simulation of a building to spring-back analysis in metal forming processes.

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