Higher order kinematic stiffening effects in 3d-shell models in sheet metal forming simulations

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ABSTRACT

In recent years, there have been many developments in the field of 3d-shell models. Compared to standard shell models, 3d-shell models allow for thickness change [1]. When simulating with only one layer of elements over the thickness, it has proven important to include linear transverse normal strains into 3d-shell models to avoid a stiffening phenomenon, often referred to as Poisson thickness locking. This is done either using the EAS-method [2] or a quadratic displacement field in thickness direction, for example [3].

When simulating bending over small radii using certain 3d-shell finite elements in LS-DYNA, [4] observed an additional stiffening effect, which remained unexplained so far. In case of large strains, the elements behave remarkably stiffer than a converged numerical reference solution, although measures to avoid Poisson thickness locking are included. If elements suffering from stiffening effects are used, damage models and failure models based on stresses are not able to represent the correct behavior, as stiffening effects usually lead to poor stress representations. In sheet metal forming applications, this fact is crucial for predicting manufacturability and crashworthiness.

This contribution focuses on explaining the additional stiffening effect described above. The stiffening effect turns out to be of higher order, which means that it is present only in case of large deformations in geometrically nonlinear simulations. Furthermore, a method to avoid the stiffening effect is derived and its feasibility is confirmed by numerical results.

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