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Perturbation Energy Concept for Stiffened Shells Using a Mixed-Hybrid Finite Element Formulation

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Due to their complex buckling behaviour shell structures have been a subject of experimental and theoretical exploration for decades. Therefore many publications concerning stability of thin shell structures are available in the literature. Because of the significant influence on the load bearing capacity geometrical and physical imperfections are of particular interest. The sensitivity to imperfections of stiffened shells will be evaluated using the perturbation energy concept, which is introduced in [3], in conjunction with mixed-hybrid finite elements. For modelling stiffened structures mixed-hybrid elements provide the advantage that discontinuities of forces can be depicted because of their local definition. Furthermore balanced shape functions are used to avoid shear and membrane locking and improve the element behaviour for distorted meshes. All global degrees of freedom are approximated using bilinear shape functions. Due to the provision of non-linear terms in the kinematic equations of the first approximation the geometric non-linear behaviour is considered by a theory of moderate rotations. On this basis critical perturbations, which cause a snap through of the ideal structure from a stable pre-buckling to an unstable post-buckling state, are calculated. The perturbation energy concept which is among others described in [1] for a mixed formulation cannot be used with common displacement based finite elements because the identification of critical states requires a free variation of forces in the elastic potential. Whereas it is shown that the perturbation energy concept is transferable to a mixed-hybrid formulation and thus can be used in conjunction with elements which contain only displacement and rotational degrees of freedom on system level.

The modifications are validated by solving the resulting non-linear quadratic eigen value problem for particular structures and comparing the results with solutions for mixed elements given in [2]. Subsequently the influence of stiffeners on critical perturbation shapes is studied for stiffened cylindrical shells and a failure criterion is developed by adjusting the calculated energy to experimental data. The results are discussed in relation to standard specifications concerning design of cylindrical steel shells.

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