A numerical-asymptotic framework based on the *ps*-FEM for the analysis of laminated shells

Abstract

Numerical methods and solution procedures for simulating nonlinear phenomena are of prime importance in engineering practice. In the field of aerospace engineering, Finite Element (FE) [1] and iterative-incremental procedures [2] are typically employed for solving nonlinear structural problems. Despite the great flexibility and effectiveness of such numerical procedures, they often require long computational times due to the large number of degrees of freedom associated to the FE discretization and the iteration steps required by the solution method.

To overcome these difficulties, the present work presents a numerical-asymptotic framework based on two pillars: an advanced FE scheme, called the *ps*-version of the Finite Element Method (*ps*-FEM) [3]; an asymptotic solution approach, known as the Asymptotic-Numerical Method (ANM) [4].

The first pillar, the *ps*-FEM, enables to easily tailor the numerical discretization to the specific problem at hand. This is achieved by increasing the polynomial order of the elements (*p*-refinement), and/or superposing meshes with different resolutions (*s*-refinement). Simultaneous *p*- and *s*-refinements enable to enhance the interpolation capability only where needed, thus helping to improve the ratio between accuracy and problem's size.

The second pillar, the ANM, seeks the numerical solution through an asymptotic expansion around a known equilibrium point. The computational cost is greatly reduced owing to the transformation of the nonlinear problem into a sequence of linear ones, solved efficiently with a single matrix factorization. Furthermore, the range of validity of the solution can be enlarged by rewriting the expansion from a new initial point. This enables complex nonlinear equilibrium paths to be represented accurately.

The purpose of this work is to show applications of this new framework to the nonlinear analysis of shell problems. Different nonlinear problems are addressed, such as postbuckling and nonlinear vibrations of isotropic and laminated panels. Comparisons with standard FE schemes and iterative-incremental approaches give evidence of the accuracy and efficiency of the proposed framework.

References

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