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FAST ANALYSIS OF POSTBUCKLED CURVILINEARLY STIFFENED PANELS

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Summary: The work covers the development of a fast approach for the nonlinear analysis of variable stiffness composite panels with curvilinear stringers. The postbuckling response is investigated for loading conditions of compression and shear. The method is developed based on First Order Shear Deformation (FSDT) theory and beam modeling for the stringers. The solution is sought in the context of the Ritz approximation. The so obtained tool is a powerful mean for addressing the potential of innovative configurations designed to operate in the postbuckling regime and offering a high degree of design tailoring due to non-uniform stiffness properties.

1 INTRODUCTION

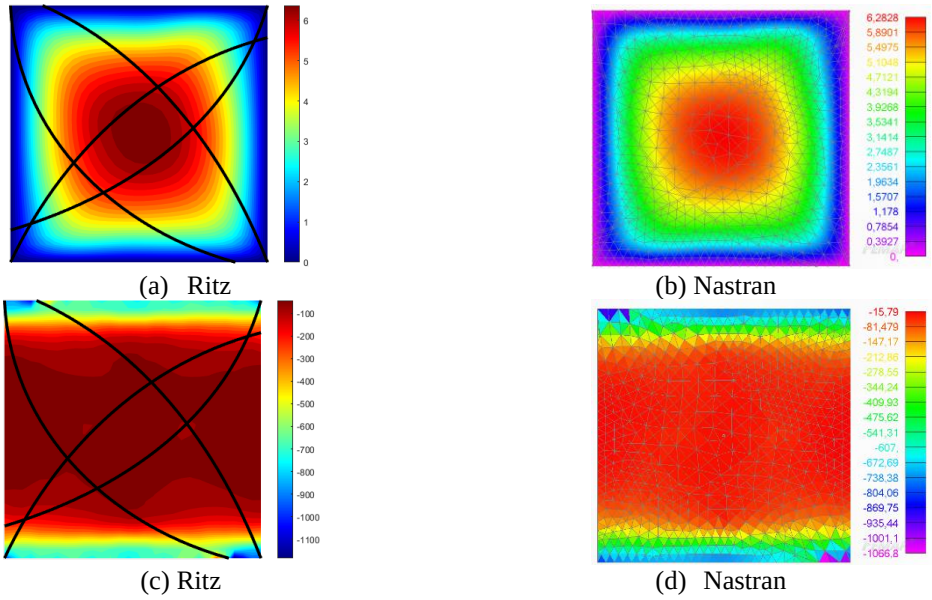
The seek for efficient structures is a constant challenge in the aerospace field. Growing interest has been recently devoted to variable stiffness (VS) laminates, offering the potential to achieve weight saving due to improved design flexibility. Similarly, improved efficiency could be obtained by relaxing topological constraints on classical stringer-stiffened configurations and by allowing the stiffener path to run along curvilinear directions. The combination of skins with variable stiffness properties and curvilinear stiffeners is then a promising chance to further improve the design tailoring of classical aerospace constructions. Recent works are found focusing on the linear buckling and vibration response of these new structures [1-4]. Investigations addressing the nonlinear response are scarce, although crucial for further understanding their potential as load bearing components. The present work stems from previous investigations focusing on the linear case [3,4] and aims at extending the field of application of the formulation to the nonlinear postbuckling regime.

2 FORMULATION

A semi-analytical formulation is developed in the framework of a displacement-based approach. The plate kinematics relies upon First Order Shear Deformation Theory (FDST), which turns to be particularly suited for handling the compatibility requirements between the skin and stringers. Geometric nonlinearities, both for the plate and the curvilinear stringers, are accounted for in the context of von Kármán-like approximations.
The problem is formulated by referring to the Principle of Virtual Work, where the unknown fields are approximated using global Ritz functions, in the framework of a total Lagrangian approach. The set of resulting nonlinear algebraic equations are solved in the context of an incremental-iterative approach based on the Newton-Raphson scheme. Special care is given to the implementation of the formulation to guarantee reduced time for analysis.

3 RESULTS

Exemplary results are presented for the postbuckling response of a VS panel with five curvilinear stringers [1]. The plate is loaded in pure compression through an imposed axial displacement at the two longitudinal sides. The load is applied up to a total shortening Δu corresponding to five times the linearized buckling condition Δu_{cr}. Hence, the investigation is extended up to the moderately deep postbuckling field. An imperfection is introduced with shape corresponding to the first buckling mode and amplitude equal to 10% of the skin thickness. The contours of the out-of-plane deflection and the membrane resultant N_{xx} are reported in Figure 1, where the comparison against Nastran finite element results is illustrated.



(a) Ritz (b) Nastran

(c) Ritz (d) Nastran

Figure 1: Postbuckling response of curvinearly stiffened VAT plate at $\Delta u=5\Delta u_{cr}$: (a), (b) out-of-plane deflection, (c), (d) membrane force N_{xx}.

As seen, close agreement is observed both in terms of deflected shapes as well as membrane forces. The proposed method allows the analysis to be run in few seconds, and no time for the modeling is needed. Both these features are essential for properly assessing the nonlinear behaviour of structures characterized by a relatively complex configuration, such as the ones investigated here.

References

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