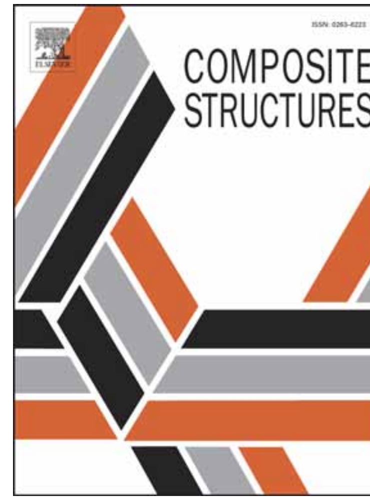

Mixed shell element for static and buckling analysis of variable angle tow composite plates

G. Zucco, R.M.J. Groh, A. Madeo, P.M. Weaver

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Mixed shell element for static and buckling analysis of variable angle tow composite plates

G. Zucco[b], RMJ Groh[a], A Madeo[b,*], PM Weaver[a]

[a]ACCIS, University of Bristol, Queen's Building, University Walk, Bristol, BS8 1 TR, UK
[b]DIMES, University of Calabria, Ponte P. Bucci Cubo, 87036 Rende (Cosenza), Italy

Abstract

A mixed quadrilateral 3D finite element, obtained from the Hellinger-Reissner functional, is presented for linear static and buckling analyses of variable-angle tow (VAT) composite plates. Variable-angle tows describe curvilinear fiber paths within composite laminae and are a promising technology for tailoring the buckling and post-buckling capability of plates. Due to the variable stiffness across the planform of the VAT plates, pre-buckling stresses can be tailored and redistributed towards supported edges, thereby greatly improving the buckling load. A linear mixed element called MISS-4 is used as starting point for this work. The element presents a self-equilibrated and isostatic state of stress. The kinematics lead to element compatibility matrix calculations based solely on the interpolation along element edges. The drilling rotations do not require penalty functions or non-symmetric formulations, thus avoiding spurious energy modes. The buckling analysis is reliably performed via a co-rotational formulation. In this work VAT plates with linear fibre angle variation in one direction, and constant stiffness properties in the orthogonal direction are studied. Numerical examples of VAT plates subjected to different loads and boundary conditions are investigated herein. The convergence of displacements, stress resultants and buckling loads are presented, and comparisons with numerical results, obtained using the S4R finite element of Abaqus and the pseudo-spectral differential quadrature method, are shown.

Keywords: Composite plates, variable angle tow, mixed finite element, Hellinger-Reissner, static and buckling analyses.

1. INTRODUCTION

Thin-walled structures are the most widely used form of construction in a number of different engineering applications, ranging from fuselages and wings in the aerospace industry aerospace to car panels in the automotive sector and ship hulls in the naval industry. In these applications the thin-walled construction allows the shape-defining outer skin of the body to become an active load-carrying member of the structure, thereby increasing the structural efficiency by combining aerodynamic and structural functions in one. Whereas thin-walled structures are efficient in carrying membrane loading, the thin-skinned construction means that compression and shear buckling become likely forms of failure.

Hence, a realistic evaluation of the structural performance of thin-walled structures requires nonlinear phenomena, such as the loss of stability, to be correctly accounted for [1]. Above all, in the case of careful structural optimization [2–7], multimodal buckling interaction [8] can induce complex post-critical behavior that strongly affects the load carrying capacity [9]. In this case the sensitivity of the structural behavior to imperfections has to be carefully investigated.

*Corresponding author. antonio.madeo81@unical.it