RECENT ADVANCES IN REFINED ZIGZAG THEORY AND ITS FINITE ELEMENT APPROXIMATIONS FOR BEAMS AND PLATES

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Abstract

The Refined Zigzag Theory (RZT) is a recently developed structural theory for laminated composite and sandwich beams and plates [1,2]. By incorporating cross-sectional kinematic distortions due to transverse-shear heterogeneity in an efficient manner, the theory constitutes a natural extension of first-order shear-deformation theories (FSDT) of Timoshenko, Reissner, and Mindlin. To date, RZT has been developed for linear and geometrically nonlinear deformations for elasto-static and elasto-dynamic behavior of laminated composite, sandwich, and functionally graded materials. Two versions of RZT currently exist: one derived from the principle of virtual work (e.g., [1,2]), and the other from Reissner's mixed-field variational principle, $RZT^{(m)}$ [3,4]. The latter theory has the advantage of incorporating the highly accurate transverse-shear stresses that satisfy equilibrium conditions along all layer interfaces. Recently, an important application of RZT to the modeling of delaminations, including the predictions of onset and propagation of damage has been demonstrated without the use of cohesive elements [5]. Numerous numerical investigations showed that RZT/$RZT^{(m)}$ is highly accurate in predicting not only the static response but also the natural frequencies and the buckling loads of laminated composite and sandwich plates without requiring any shear correction factors [6]. Comparisons with experimental measurements have also been successful [7].

This paper presents an overview of the theoretical foundations of both RZT and $RZT^{(m)}$, and addresses suitable finite element approximations that properly approximate the unique penalty-constraint aspects of this theory. Importantly, the kinematic variables are approximated using simple C^0-continuous functions. Thus, both RZT and $RZT^{(m)}$ can be readily adopted to derive reliable and computationally efficient finite elements suitable for large-scale analyses of a wide range of material systems and structures (e.g., [8]).

References

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