Buckling and Vibration Behaviour of the Debonded Stiffened Hygrothermally Stable Laminated Composite Panel Under the Influence of Non-Uniform Edge Loads.

abst. 1228
Virtual Room 2
Wednesday
July 20
12h30

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T- stiffeners are widely used in the aerospace, civil, and marine industries because they provide better resistance to buckling modes. However, in addition to external loading, these panels are subjected to extreme temperature and moisture conditions during their service and may undergo damage as a result of stresses developed due to hygrothermal and mechanical loading. Thereby, to analyse the structure, an investigation is carried out to understand the buckling and dynamic behaviour of the stiffened laminated composite panel that is debonded at the plate-stiffener flange interface subjected to non-uniform edge load under the influence of a hygrothermal environment. The investigation is carried out by employing a reliable and computationally efficient finite element (FE) formulation. It is important to note that a large amount of experimental investigation is available on the hat stiffened panel. In contrast, quite a few studies are available on the debonded stiffened panel using an analytical or semi-analytical approach and by employing Finite element software. In the past investigation, the stiffened panel was modelled using a 3D- brick element or a 2-D shell element, which would increase the computational cost. However, in the current investigation, the skin and the stiffener flange are modelled using a 9-noded heterosis plate element to avoid the shear locking problem. The web of the stiffener is modelled using a 3-noded isoparametric beam element by incorporating the torsion correction factor, which will slightly reduce the computational cost. The current model applies the displacement continuity condition at the plate-flange interface in the bonded region to emphasise the stiffener flange's nodal displacement in relation to the plate's nodal displacement. However, in the debonded region, a dummy independent node is created, and the fictitious spring is inserted between the parent and the dummy nodes to prevent the interpenetration of nodes. The current investigation is carried out on the three schemes of hygrothermally stable laminates that were considered based on the earlier researcher's observation. The lamina scheme (/90-)s is the configuration that induces equal normal non-mechanical stress resultants and zero non-mechanical shear and moment resultants. (-67.5/22.5)s is the lamina scheme with an optimal shear extension co-efficient, whereas (77.5/-12.5)s is the lamina scheme with an optimal value between the bending stiffness and compliance. As the stress developed by the environmental and operational conditions is highly non-uniform in nature, a dynamic approach is used to calculate the buckling parameter of the stiffened panel by employing two sets of boundary conditions. Initially, a study is conducted to determine an optimal stiffener configuration with improved performance based on the vibration and buckling behaviour. Detailed parametric investigations are then carried out to examine the effect of debonding size, debond position, aspect ratio and stiffener depth to width ratio on the buckling and vibration performance of the optimal stiffened panel subjected to non-uniform edge load under the influence of hygrothermal environment. It is observed that moisture significantly influences the panel's performance than the temperature. The panel's performance drops suddenly when the hygrothermal load approaches the critical temperature or moisture level. Furthermore, there is no discernible effect of hygrothermal load on the panel performance with small size debond. However, as the debond size increases, there is a substantial drop in the panel's behaviour.

A new mixed model based on the enhanced-Refined Zigzag Theory for the analysis of thick multilayered composite plates

abst. 1231
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The Refined Zigzag Theory (RZT) has been widely used in the numerical analysis of multilayered and sandwich plates in the last decay. It has been demonstrated its high accuracy in predicting global

quantities, such as maximum displacement, frequencies and buckling loads, and local quantities such as through-the-thickness distribution of displacements and in-plane stresses [1,2]. Moreover, the C0 continuity conditions make this theory appealing to finite element formulations [3]. The standard RZT, due to the derivation of the zigzag functions, cannot be used to investigate the structural behaviour of angle-ply laminated plates. This drawback has been recently solved by introducing a new set of generalized zigzag functions that allow the coupling effect between the local contribution of the zigzag displacements [4]. The newly developed theory has been named enhanced Refined Zigzag Theory (en-RZT) and has been demonstrated to be very accurate in the prediction of displacements, frequencies, buckling loads and stresses. The predictive capabilities of standard RZT for transverse shear stress distributions can be improved using the Reissner's Mixed Variational Theorem (RMVT). In the mixed RZT, named RZT(m) [5], the assumed transverse shear stresses are derived from the integration of local three-dimensional equilibrium equations. Following the variational statement described by Auricchio and Sacco [6], the purpose of this work is to implement a mixed variational formulation for the en-RZT, in order to improve the accuracy of the predicted transverse stress distributions. The assumed kinematic field is cubic for the in-plane displacements and parabolic for the transverse one. Using an appropriate procedure enforcing the transverse shear stresses null on both the top and bottom surface, a new set of enhanced piecewise cubic zigzag functions are obtained. The transverse normal stress is assumed as a smeared cubic function along the laminate thickness. The assumed transverse shear stresses profile is derived from the integration of local three-dimensional equilibrium equations. The variational functional is the sum of three contributions: (1) one related to the membrane-bending deformation with a full displacement formulation, (2) the Hellinger-Reissner functional for the transverse normal and shear terms and (3) a penalty functional adopted to enforce the compatibility between the strains coming from the displacement field and new "strain" independent variables. The entire formulation is developed and the governing equations are derived for cases with existing analytical solutions. Finally, to assess the proposed model's predictive capabilities, results are compared with an exact three-dimensional solution, when available, or high-fidelity finite elements 3D models. References: [1] Tessler A, Di Sciuva M, Gherlone M. Refined Zigzag Theory for Laminated Composite and Sandwich Plates. NASA/TP-2009-215561 2009:1–53. [2] Iurlaro L, Gherlone M, Di Sciuva M, Tessler A. Assessment of the Refined Zigzag Theory for bending, vibration, and buckling of sandwich plates: a comparative study of different theories. Composite Structures 2013;106:777–92. https://doi.org/10.1016/j.compstruct.2013.07.019. [3] Di Sciuva M, Gherlone M, Iurlaro L, Tessler A. A class of higher-order C0 composite and sandwich beam elements based on the Refined Zigzag Theory. Composite Structures 2015;132:784–803. https://doi.org/10.1016/j.compstruct.2015.06.071. [4] Sorrenti M, Di Sciuva M. An enhancement of the warping shear functions of Refined Zigzag Theory. Journal of Applied Mechanics 2021;88:7. https://doi.org/10.1115/1.4050908. [5] Iurlaro L, Gherlone M, Di Sciuva M, Tessler A. A Multi-scale Refined Zigzag Theory for Multilayered Composite and Sandwich Plates with Improved Transverse Shear Stresses, Ibiza, Spain: 2013. [6] Auricchio F, Sacco E. Refined First-Order Shear Deformation Theory Models for Composite Laminates. J Appl Mech 2003;70:381–90. https://doi.org/10.1115/1.1572901.

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Numerical stability analysis of composite beam-type structures considering coupled shear deformation effects

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A free shear-locking beam model for numerical stability analysis of composite beam-type structures is presented. The incremental equilibrium equations for a straight fourteen-degree-of-freedom beam element are derived within the framework of updated Lagrangian formulation. In this, the nonlinear displacement field of a thin-walled cross-sections, accounting for the restrained warping and the large rotations effects, is applied. The applied shear-deformable beam formulation accounts for the flexural-torsional coupling appearing when a non-symmetric cross-section is considered. Cross-section properties are calculated using the reference modulus, which enables to model various cross-ply cross-sectional wall configurations. The numerical algorithm is implemented in a computer program and validated through several benchmark examples.