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Static and dynamic NURBS-based isogeometric analysis of composite plates under hygrothermal environment

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ABSTRACT

In this paper, a computationally efficient isogeometric plate model, employing nonpolynomial shear deformation theory (NPSDT), for static and dynamic analysis of laminated and sandwich composite plates under hygrothermal environment is presented. Transient and steady-state response using Rayleigh damping model and fast Fourier transformation of transient response have also been obtained for the hygrothermal environment. The non-uniform rational B-splines (NURBS) based formulation has been considered, which attribute only five-degree of freedom and satisfies the stringent continuity requirement of the NPSDT model (C^1-continuity) without any additional variables. A total Lagrangian approach in conjunction with Hamilton's principle is utilized to formulate the governing equations for thermal bending and subsequent dynamic analysis of multilayered composite plates. To model stress stiffening effect due to hygrothermal load, both von Kármán and Green–Lagrange strain displacement relations are incorporated and obtained solutions are compared. It has been shown that at higher temperature (around one fourth of the critical buckling temperature), the consideration of Green–Lagrange strain relationship for modeling stiffening effect due to hygrothermal load is important for better accuracy. Further, it has been shown that bending strip is essential in case of higher-order shear deformation theory (HSDT) to get more accurate solution. In addition, the obtained transient damped/undamped solutions may be used to get the natural frequency from their FFT solution.

1. Introduction

Today's requirement for the highly effective and efficient material, concerned with the eco-friendly world of finite resources, has made the advanced composites to be one of the most important materials for the structural engineering. In the past few decades, laminated and sandwich composite structures achieved comprehensive recognition in industries like aerospace, mechanical, automotive, marine, etc. This is generally because of its excellent mechanical properties such as high stiffness-to-weight ratio, high strength-to-weight ratio, high impact, fatigue and corrosion resistance, and their easy tailoring capability to design any shape over the isotropic materials. However, the influence of transverse shear deformation is crucial in composites, due to their low shear to extensional modulus ratio, and cannot be ignored even for thin plate. Thus, structural analysis must consider the effect of shear deformation to fully utilize the performance of multilayered composite structures for wide range of applications. As a result, several approximate plate theories have been developed by various researchers to evaluate the structural responses of multilayered composite structures under static and dynamic loads. For instance, first-order shear deformation theory (FSDT), which includes constant transverse shear deformation with only C° continuity of generalized displacement, became popular [1] in compare to classical laminated plate theory (CLPT) which completely ignores transverse shear effects. Further, a shear correction factor has been introduced to adjust the transverse shear energy of FSDT. However, the accuracy is difficult to ascertain due to dependency of the shear correction factor on the lamination sequence, loading conditions, and boundary conditions [2,3]. Later on, these limitations of FSDT have been overcome by the introduction of higher-order shear deformation theories (HSDTs). In general, transverse shear deformations are modeled using HSDT which either considers the displacement field of higher-order terms from Taylor's series expansion, called polynomial shear deformation theories (PSDTs) [4], or utilizes nonpolynomial function in the

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