Stochastic vibrational characteristics estimation of delaminated variable angle tow laminated plates

[1] Narayan Sharma, India
[2] Prateek Chandrakar, India
[3,†] Dipak Kumar Maiti, India

[1] narayan.sharma43450@gmail.com
[2] pch.prateek@gmail.com
[3,†] dkmaiti@aero.iitkgp.ac.in

[1,2,3] Department of Aerospace Engineering,
Indian Institute of Technology, Kharagpur, India.

Abstract

This research discusses the effect of delamination on the free vibrational response of VAT plates. For parametric analysis, VAT plates with changing fiber angles are confined to several boundary conditions. The contribution of composite properties of delaminated and intact plates is then evaluated using a comparative stochastic vibration analysis. The efficient Latin hypercube sampling (LHS) approach is used to approximate the randomness in the material properties. The PNN-based surrogate model, which is thought to be an efficient substitute for computationally expensive Monte Carlo simulation (MCS), is used in this study to investigate the stochastic behavior of VAT plates.

Fiber-reinforced composite laminates with high strength-to-weight and stiffness-to-weight ratios are becoming increasingly essential in weight-sensitive applications like aviation and space vehicles. Constant stiffness composite laminates, which are composite materials with straight fiber spacing, have been conventionally employed and offer numerous benefits. It is feasible that manipulating the trajectory of the fibers through the incorporation of supplementary curves could potentially augment mechanical efficacy in a range of manners. The composites under consideration are referred to as variable angle tow (VAT) laminates. These composites allow for the manipulation of stiffness across the material, resulting in improvements in mechanical properties. Hyer and Lee [1] investigated on the buckling performance enhancement of a simply supported plate with a centrally positioned hole. The study proposed that the presence of curved fibers could potentially enhance the redistribution of stress away from the hole location, hence leading to improvements. In their research, Honda and Narita [2] put out the proposition that assigning a unique curvilinear trajectory to each layer of composite laminates could provide separate vibration mode forms. Tian et al. [3] conducted a study on the optimization of fiber path by the manipulation of design parameters, namely expansion coefficients.

Composite laminates are commonly utilized in complex situations and subjected to a variety of dynamic stresses; the components may break and collapse owing to material fatigue produced by intense vibrations. As a result, it is becoming increasingly important to understand structural vibrations and eradicate them in order to enhance the performance of structures and fully utilize them. Due to the intricacy of the procedures employed in composites manufacturing, accurate ply alignment, flawless resin curing, the optimal amount of resin between plies, and the absence of interlaminate and matrix voids are difficult to achieve. Composite constructions are more prone to damage due to inherent manufacturing defects and varying service conditions. Composite damage can take numerous forms, including delamination, matrix cracks, fiber breakage, fiber-matrix de-bonding, and so on. Delamination is one of the most serious types of laminated composite deterioration. Tiwari et al. [4] used three-dimensional degenerated elements on delaminated plates to conduct their research. Material uncertainty quantification over variable fiber spacing composite laminates is performed by Chandrakar et al. [5].

Keywords: curvilinear fibers, delamination, variable stiffness composite laminate

Results and highlights of important points

1) It is discovered that delamination along the fixed edge of cantilever plates has a significant impact on vibration characteristics, whereas centrally positioned delamination has a significant impact on SSSS and CCCC VAT plates.
2) The frequency was lowered the most in the mid relative delamination location.
3) The highest dispersion is recorded for mode-3 VAT laminates.
4) For all of the analyzed instances, the most sensitive free vibration parameters are density, young's modulus, and fiber orientations.

†Corresponding Author : D. K. Maiti, Tel: +91-9933030201, E-mail: dkmaiti@aero.iitkgp.ac.in

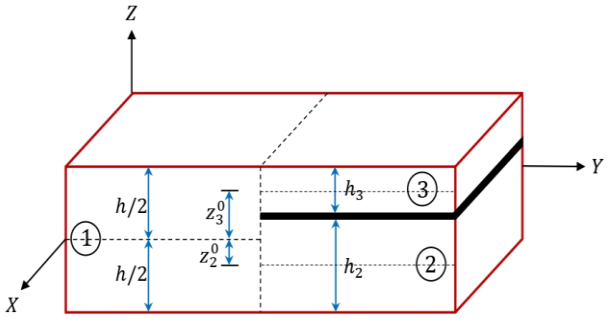

Figure 1: Delamination at the crack tip

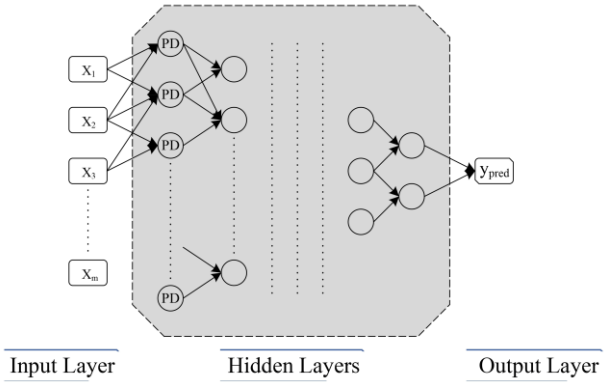

Figure 2: PNN structure

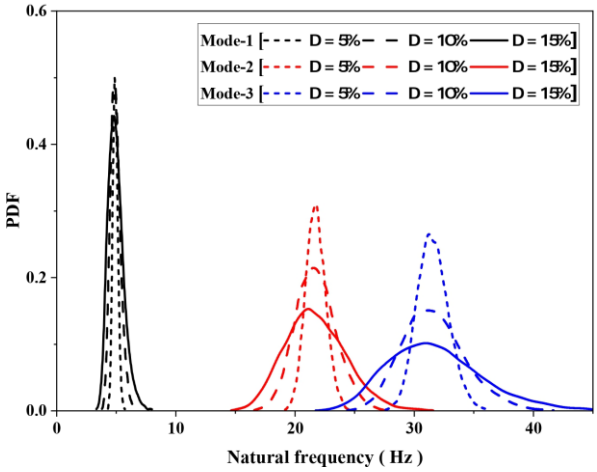

Figure 3: Comparative stochastic PDF plot for VSCL plate

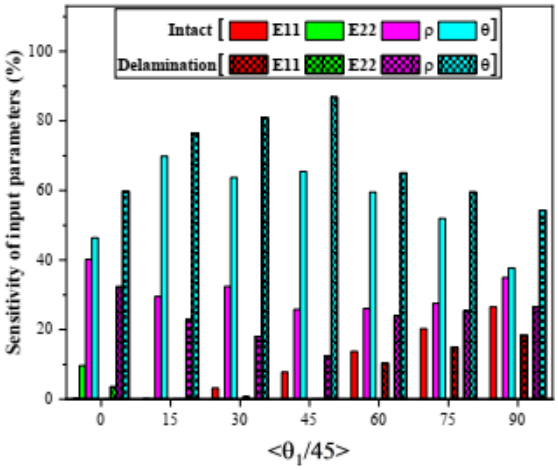

Figure 4: Sensitivity estimation of four most influential properties

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