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Effect of delamination on the stochastic natural frequencies of composite laminates

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Abstract

The coupled effect of manufacturing uncertainty and a critical service-life damage condition (delamination) is investigated on the natural frequencies of laminated composite plates. In general, delamination is an unavoidable phenomenon in composite materials encountered often in real-life operating conditions. We have focused on the characterization of dynamic responses of composite plates considering source-uncertainty in the material and geometric properties along with various single and multiple delamination scenarios. A hybrid high dimensional model representation based uncertainty propagation algorithm coupled with layer-wise stochastic finite element model of composites is developed to achieve computational efficiency. The finite element formulation is based on Mindlin's theory considering transverse shear deformation. Numerical results are presented for the stochastic natural frequencies of delaminated composites along with a comprehensive deterministic analysis. Further, an inevitable effect of noise is induced in the surrogate based analysis to explore the effect of various errors and epistemic uncertainties involved with the system.

Keywords: delamination; manufacturing uncertainty; laminated composite plate; surrogate based finite element method

1. Introduction

Laminated composites have gained preference in various engineering applications such as aerospace, naval, automobile, micro-electro-mechanical-systems (MEMS) and civil structures due to high strength and stiffness with weight-sensitivity, increased toughness, mechanical damping, as well as tailoring of structural properties. In the recent year, wide application of composite materials has drawn an increased attention to its operational reliability and safety. The exhaustive usage of such structures has warranted the detail understanding of damage modes and their consequences in global structural responses. One of the most