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Free vibration analysis of stiffened and cracked laminated composite plate assemblies using shear-deformable dynamic stiffness elements

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Abstract

In the paper, the dynamic stiffness method based on HSDT and FSDT plate theories is applied to study free vibration characteristics of composite stiffened and cracked plate assemblies. The dynamic stiffness matrices for transverse vibration of laminated composite plate based on HSDT and FSDT previously derived by authors have been coupled with the dynamic stiffness matrix of laminated composite plate undergoing in-plane vibration. The numerical analysis has been carried out through several illustrative examples in order to check the applicability and accuracy of the proposed method in the free vibration analysis of stiffened plate assemblies. The effects of transverse shear deformation, boundary conditions, side-to-thickness ratios, crack length or reinforcement amount within the GFRP beam on the free vibration characteristics have been discussed, and the variety of new results has been provided as a benchmark for future investigations.

Keywords: dynamic stiffness method, free vibration, composite plate assembly, crack

1. Introduction

Composite laminates are nowadays extensively applied in many engineering disciplines, as structural components of aircraft wings, ship hulls, FRP bridges, rotor blades of wind energy converters, wall and roof panels, etc. In addition, fiber reinforced polymer (FRP) pultruded profiles are being increasingly used as structural members in civil engineering applications. The free vibration characteristics (natural frequencies and corresponding mode shapes) of such structures are of great interest, because these structural components usually act in the dynamic loading environment, such as turbulent wind loading. Due to the outstanding stiffness-to-weight ratios of laminar composites, they are usually designed in the form of thin plates and shells, which are vulnerable to buckling and require the use of stiffeners. Aiming at preventing the occurrence of lateral torsional buckling phenomena in the glass-fiber reinforced polymer beams, stiffeners are usually used [1]. Conventional pultruded profiles are usually made of glass fibers (GF) embedded in a polymeric resin. Since the structural design of GFRP members is often governed by the serviceability limit states (deformability and vibrations), the partial replacement of the glass reinforcement by carbon fibers (CF) is a possible approach to improve their stiffness and consequently their buckling behavior [2]. Finally, having in mind that these structures usually consist of stiffened plates joined at different angles, coupled in-plane and bending modes of vibration occur besides the pure bending or in-plane modes (which are present for simple cases of plate geometry or boundary conditions).

Due its working life, a crack within a plate may occur from different sources (such as impact forces), which may significantly alter the dynamic properties of the plate, reducing its stiffness and changing the mode shapes and fundamental frequency. Therefore, investigation of the vibrations of cracked plate is of a great importance, as well. Taking all aforementioned reasons into account, an

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