Abstract

The present thesis is focused on the development of closed-form dynamic stiffness (DS) formulation for analysing the vibration and buckling characteristics of plates made of advanced composite materials. An accurate estimation of the vibration and buckling characteristics of plates is essential to ensure the structural integrity, safety, and optimal performance of engineering components in various applications. It is well-established that the dynamic stiffness method (DSM) has the capability to produce exact results as it considers the exact solutions of the governing differential equations of the problem in determining the dynamic stiffness matrix which is the main building bock of the dynamic stiffness method. The method has several advantages over the other numerical methods such as FEM. For example, the DSM avoids introducing approximation errors and ensures accuracy even in the computation of frequencies at higher modes. Additionally, the dynamic stiffness approach achieves convergence with fewer elements, thereby reducing computational costs. Due to these advantageous features, the DSM has been extensively used for the analysis of beam vibration problem. However, the method has not been explored, in its full extend, for the dynamic analysis of plates, especially plates made with advanced composite materials. Advanced composite materials, reinforced with particles or fibers, have found its application in several field of engineering owing to its superior mechanical, electrical and thermal properties as compared to the traditional composite materials. These materials can be graded in a preferred direction in a structural component, giving rise to a concept of functionally graded (FG) structures. In this context, the present thesis aims at the implementation of the DSM for the vibration, buckling, and prestressed vibration analysis of advanced composite plates (i.e. FGM, FG-CNTs, and FG-GPLs plates) having uniform and non-uniform plate configurations.

The displacement field, within the plate, is defined based on first-order shear deformation theory (FSDT). Hamilton's principle is used for the derivation of governing differential equations (GDEs) of motion and the associated natural boundary conditions. Assuming Levy form of solutions, the frequency-dependent dynamic stiffness matrix for a single plate element is developed. In order to analyse various uniform and non-uniform configurations of the plate, an appropriate assembly of these single element DS matrices are performed. The assembled global DS matrix is transcedental in nature and the eigenvalues of this DS matrix are computed by using the Wittrick-Williams (W-W) algorithm. W-W algorithm ensures that all the natural frequencies, even the coincidental one, are computed within a given frequency range. With this DSM approach, FGM, FG-CNTs, and FG-GPLs reinforced plates are analysed to characterize their vibration, buckling, and prestressed vibration behaviour. Various plate configurations, including stepped, folded, and corrugated plates, are studied. Plates resting on both homogeneous and non-homogeneous elastic foundation are also investigated with the DSM approach. Initially, the DSM computed results are validated with the published results as well as FEM results to ensure the correctness of the present approach. Later, parametric studies are performed to investigate the effect of various design parameters on the vibration and buckling behaviour of the plates. Many interesting observations and inferences are made based on the computed results. Finally, it can be emphasized that the new set of DSM computed results reported in the thesis, for diverse configurations of the advanced composite plates, are highly accurate and may serve as reference results for the future research studies.

Keywords: Dynamic stiffness method, Wittrick-Williams algorithm, advanced composite plates, first order shear deformation theory, free vibration, buckling, prestressed vibration