

Abstract

In this thesis a three-dimensional fractional order derivative model (FDM) for the constitutive relations of the viscoelastic constrained layer of the smart constrained layer damping (SCLD) treatment is developed by mathematically augmenting its existing one-dimensional form for analyzing active damping of geometrically nonlinear vibrations of substrate plates, shells and sandwich structures. Here, the three-dimensional FDM is established as an efficient numerical modelling technique of the viscoelastic layer compared to other viscoelastic models particularly in case of computationally involved geometrically nonlinear vibrations of plates and shells. A nonlinear finite element (FE) model is developed to obtain the time dependent electro-elastically coupled governing equation of motion of three dimensional substrate plates and shells with a SCLD patch attached at the centre of their top surface. The geometric nonlinearity is included in the model by considering von Kármán strain-displacement relations. The displacement field is assumed according to the FSDT with a layerwise effect such that accurate kinematics of deformations can be modeled whenever there is drastic change in the material properties along the thickness direction. The constraining layer is made of vertically/obliquely reinforced 1-3 piezocomposites (PZCs) and for the closed loop control a negative velocity feedback control system is considered due to its simplicity in design and ease of implementation in practical engineering problems. To ensure presence of sufficient nonlinearity in the initial responses of the structure, the amplitude of the applied loads have been selected from the backbone curves. The Grünwald definition has been implemented in this work to numerically compute the fractional order operators and numerical examples are presented considering laminated composite plates and shells to show that even for very small number of terms in the Grünwald series the obtained responses are highly accurate. Investigation also revealed that the vertically reinforced 1-3 PZCs are most effective in active damping of the substrate plates and shells vibrations irrespective of layer sequence or boundary condition. Further, Plates and shells made of fuzzy-fiber reinforced composite (FFRC) with carbon nanotube (CNT) waviness contained in different planes are studied and the presence of the CNT waviness has an impact on the performance of the SCLD patch. Maximum control authority of the SCLD patch is observed in case of the FFRC with wavy CNTs with waviness in 1-3 plane as they exhibit higher stiffness to weight ratio compared to other FFRCs. In case of sandwich plates and shells, several examples are presented to investigate the performance of the SCLD patch for different thickness ratio and core materials of the substrate sandwich plates and shells. It is found that the efficiency of the SCLD patch increases with the increase in thickness ratio whereas for different core materials the performance of the SCLD patch varies negligibly. In the final problem, the customizable variable thickness laminated composite shells with different thickness variations are considered and it is shown that the performance of the SCLD patch is improved in case of a variable thickness shell with suitable thickness variation compared to the shells with constant thickness.