Abstract

Laminated composite plates/shells structures made of fibre-reinforced composite materials are being extensively used in thin-walled structural components of the modern engineering applications, especially in the modern aircraft and aerospace industries, automotive, civil, mechanical and marine industries. These weight sensitive structures possess high stiffness to weight ratio, strength to stiffness ratio, strength to weight, excellent resistance to corrosive substances and potentially high overall durability. For these reasons, tremendous research on the development of advanced composite materials and modeling of complicated composite structures is being carried out. Skew laminates made of fibre-reinforced composite materials can be used as the primary structural elements/components. It is well known that skew, swept or oblique laminated composite plates/shells made of fiber reinforced composite materials are important structural components and have considerable significance in aerospace applications, automotive structures, ship hulls and swept wings of aeroplanes. Owing to its wide range of applications and also relative degree of simplicity, skew laminated composite plate/shell is an important vibration problem.

This dissertation work addresses the analysis of the active constrained layer damping (ACLD) of geometrically nonlinear vibrations of skew plates and shells composed of laminated composites, functionally graded (FG) and fuzzy fiber-reinforced composite (FFRC) layers. The constraining layer of the ACLD treatment is considered to be composed of the vertically/obliquely reinforced 1-3 piezoelectric composite (PZC) material. The Golla-Hughes-McTavish (GHM) method has been used to model the constrained viscoelastic layer of the ACLD treatment in the time domain. The Von Kármán type geometrically nonlinear strain-displacement relations are included in the formulation and a new displacement theory are used for deriving a coupled electro-mechanical nonlinear three dimensional finite element (FE) model to assess the performance of the skew or rectangular patches of ACLD treatment. The performances of the patches are investigated for different configurations of their placements on the top surface of the skew substrate plates and shells. Backbone curves are derived to determine

the level of the amplitude of the uncontrolled response such that the substantial nonlinearity is present in the uncontrolled response. The analyses reveal that the ACLD treatment significantly improves the active damping characteristics of the skew FG and laminated composite plates and shells over the passive damping for suppressing their geometrically nonlinear transient vibrations. The performance of the ACLD treatment is maximized if the constraining layer is made of the vertically reinforced 1-3 PZC material. Also, the analyses reveal that the ACLD treatment in which the constraining layer is made of the vertically reinforced 1-3 PZC exhibits maximum capability of causing active damping of geometrically nonlinear vibrations of both the FG plates and shells under thermal environment. In order to apply the control voltage for activating the patches of the ACLD treatment, a simple velocity feedback control law has been employed.

Finally, a novel type of skew laminated FFRC plates and shells is considered which are composed of the FFRC layers and the ACLD of geometrically nonlinear vibrations of such skew laminated FFRC substrate plates and shells using 1-3 PZC materials has been studied. The novel constructional feature of the FFRC lamina is that the short carbon nanotubes (CNTs) which are either straight or wavy are radially grown on the periphery of the long continuous carbon fiber reinforcements of the FFRC lamina. The analyses reveal that the ACLD treatment in which the constraining layer is made of the vertically reinforced 1-3 PZC material maximizes the damping of the geometrically nonlinear vibrations of the FFRC plates and shells. The investigation also reveals that if the fiber reinforcements of the composite skew plates and shells are coated with radially grown straight or wavy CNTs, the performance of the ACLD treatment increases as compared to that without CNTs. More importantly, it is found that the performance of the ACLD treatment is better in case of controlling the geometrically nonlinear vibrations of the skew laminated FFRC plates and shells with wavy CNTs than that in case of controlling the same with straight CNTs. Thus it is suggested that the wavy CNTs can be properly exploited to gain structural benefits from the exceptional properties of CNTs and develop high performance smart structures superior to the existing ones.