Abstract

The principal aim of this thesis is to analyse the effectiveness of multifunctional composites as intelligent structures to improve mechanical properties and activate additional non-structural features. In order to investigate these multiple aspects, a comprehensive literature review has been presented focusing on the state-of-the-art in multifunctional composites. The importance of simultaneous consideration of the nonlinearly-coupled functions in a multifunctional device is demonstrated.

The development of an analytical model for a multilayer stack subjected to temperature change is demonstrated here. Thin continuous layers of materials bonded together deform as a plate due to their differing coefficients of thermal expansion and/or shear on subjecting the bonded materials to the change in temperature. Applications of such structures can be found in the electronic industry in printed circuit boards for the study of warpage issues or in the aerospace industry as laminated thin sheets used as skin structures for load-bearing members such as wings and fuselage. In avionics, critical high-power packages (IGBT, Power FETs) include several layers of widely differing materials (Aluminum, Solder, Copper, ceramics) subjected to a wide range of cyclic temperature changes. Modeling of such structures by the application of three-dimensional finite element methods is usually time-consuming and may not accurately predict the interlaminar strains. Efforts have been made here to obtain closed-form solutions for such a multilayered stack using a set of recursive polynomial equations on subjecting the stack to temperature changes under steady-state conditions. These efforts focused on investigating laminate mechanical properties, as well as preliminary coupled electrical-structural-thermal micromechanical analyses. Several carbon reinforcing materials and potential laminate orientations were analyzed through both FEM and analytical methods to determine laminate flexural properties.

In the second phase of the work, investigation on the directionality of sound radiated from a rectangular panel, attached with masses/springs, set in a baffle, is studied. The attachment of masses/springs is done based on the receptance method. Receptance method is used to generate new mode shapes and natural frequencies of the coupled system, in terms of the old mode shapes and natural frequencies. The Rayleigh integral is then used to compute the sound field. The point mass/spring locations are arbitrary, but chosen with the objective of attaining a unique directionality. The excitation frequency to a large degree decides the sound field variations. However, the size of the masses and the locations of the masses/springs do influence the new mode shapes, and hence the sound field. The problem is more complex when the number of masses/springs are increased and/or their values are made different. The technique of receptance method is demonstrated through a steel plate with attached point masses in the first example. In the second and third examples, the present method is applied to estimate the sound field from a composite panel with attached springs and masses, respectively. The layup sequence of the composite panel considered in the examples corresponds to the multifunctional structure battery material system, used in a micro air vehicle (MAV). The demonstrated receptance method does give a reasonable estimate of the new modes.

In the third phase of this work, effects of the multifunctional composites on a few critical aeroelastic features have been investigated. The relevant modes used for the computation of flutter have been experimentally validated and mode assurance criteria (MAC) using DEW software is utilized to ascertain relevant modes. Some computational case studies related to both high-speed and low-speed unmanned aerial vehicles have been completed.

Keywords: Multifunctional Composites, Unmanned Aerial Vehicles, Finite Element Method.