Analysis of Multifunctional SMA/Piezoelectric/Composite Beam Structure for Morphing and Energy Harvesting

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ABSTRACT

Morphing is defined as the ability of certain wing to change its geometrical form during flight. Morphing concept is inspired from bird wings that are able to change wing shapes during flight at varied surrounding conditions. Such wing will enable the aircraft to accommodate multiple flight regimes and obtain better flight performance. There can be several types of morphing possible viz. span, chord, sweep, chord-wise, span-wise and twist etc. Several mechanisms are reported in literature to achieve particular type of morphing. Of late multifunctional smart materials are being developed to achieve several functionalities simultaneously. Apart from multiple functionalities these materials can reduce weight of the structure thus enable fuel savings. Present work proposes to develop a new innovative multifunctional smart material composed of SMA and piezoelectric smart materials along with conventional composites like glass/epoxy, carbon/epoxy etc as a laminated hybrid composite material. The hybrid composite considered for present study is having beam structure. One dimensional Tanaka type model proposed by Brinson is adopted to model SMA behaviour. As Young's modulus is dependent on martensite fraction, the transformation model of SMA is solved along with constitutive relation by Newton-Raphson scheme. Reuss scheme is used to predict Young's modulus of SMA containing austenite and martensite phases. Strength of materials approach is adopted to predict effective properties of piezoelectric composite. Effective properties of laminated hybrid composite beam are estimated from multicell micromechanical approach. The objective of the present work is to analytically investigate the free vibration of this newly proposed hybrid composite beams in pre/post-buckled domains and also to analytically estimate energy harvesting capability. Non-linear equations of motion of proposed hybrid composite beam are derived based on the first-order shear deformation theory and von Karman geometrical non-linearity via the extended Hamilton principle. The recovery stress generated by temperature-induced martensitic phase transformation of the pre-strained SMA fiber is computed by means of the Brinson model. Solutions of simply supported boundary conditions of hybrid composite beam are presented for the buckling temperature, post-buckling deformation and temperature-deformation equilibrium path of hybrid composite beams under aerodynamic loads. The effectiveness of this hybrid composite on variable camber morphing is investigated. The vibration of the hybrid composite beam around the first buckled configuration is also investigated and solution for the fundamental frequency and its associated mode shape is obtained. Numerical results are presented on buckled shapes, variable camber morphing, vibration frequency and mode shapes, stress recovery and energy harvesting capabilities of this hybrid composite beam.

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