Buckling Detection Using Carbon Nanotube Reinforced Composite Sensors

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Abstract: Enhancing the strength-to-weight ratio in structural engineering has traditionally attracted great research efforts from both scientist and practicing engineers. Development of new composite materials and/or alternative structural configurations have led to slender designs, which may be prone to buckling failure. Meanwhile, the most recent advances in the field of Nanotechnology have allowed the development of new composite materials with not only low weight and adequate load-bearing capacity, but also additional self-sensing capabilities. Such multifunctional composites open a vast range of possibilities in the field of Structural Health Monitoring. In particular, this work analyzes-from a numerical perspective-the effective implementation of carbon nanotube (CNT) reinforced epoxy strip-like sensors on a beam structure to assist in detecting buckling failure.

To this aim, CNT-reinforced epoxy strips are installed on both the upper and bottom surfaces of a beam-like structure. The addition of CNT in small concentrations has proven to improve the mechanical properties of the base polymer materials while further confering a piezoresistive behavior to the resulting smart composite, so that the load-induced mechanical deformations lead to measurable variations in the electrical properties of the composite. In this manner, the proposed buckling detection procedure follows from the changes recorded on the electrical resistance of the sensing strip induced by the variations of the normal bending strains produced during buckling. The multifield behavior of the smart beam is simulated by a combination of a micromechanics-based piezoresistivity model implemented within a macroscopic finite element model. The theoretical estimates of the electromechanical constitutive properties of CNT-based composites have been satisfactorily benchmarked against experimental results in the literature. Subsequently, parametric analyses have been conducted to analyze the correlation between the electrical response of the beam and its buckling behavior. The numerical results clearly show that buckling failure can be traced through sudden disturbances in the electrical output of the smart strips. Therefore, such CNT reinforced strips may cover a twofold objective: they do not only reinforce the host beam but do perform as well as valid sensors to detect buckling.

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