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Active Vibration Control of Smart Functionally Graded Beams

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Abstract

This work is devoted to examine the performance of the constraining layer of the active constrained layer damping (ACLD) treatment made of the active fiber composites (AFC) materials for vibration control of functionally graded (FG) beams. The task of investigating the performance of the active constrained layer damping (ACLD) treatment has been accomplished to demonstrate the use of AFCs as the materials for distributed actuators. Finite Element (FE) model is developed to describe the open loop and closed loop dynamics of the FG beams integrated with the patches of the ACLD treatment. The closed loop frequency response functions computed by the FE models reveal that the ACLD treatment with its constraining layer composed of AFC material significantly enhances the damping characteristics of the FG beams.

The performance of the ACLD treatment when the orientation angle of the piezoelectric fibers of the AFC constraining layer is varied has also been investigated. Such variation of piezoelectric fiber orientation angle significantly affects the controllability of the ACLD treatment for active damping of the FG beams. The investigations carried out here may be useful for further experimental verifications and suggest the potential use of AFC materials for developing new distributed actuators of light-weight smart structures.

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Keywords: Functionally Graded Beams, ACLD, Frequency Response, Finite Element Model, Closed Loop.

1. Introduction

Smart materials are the materials in which one or more properties can be significantly changed in a controlled fashion by external agents such as stress, temperature, moisture, electric or magnetic fields. These materials have properties that react to changes in their environment. This means that one of their properties can be changed by an

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external condition, such as temperature, light, pressure or electricity. This change is reversible and can be repeated many times. There are many groups of smart materials, each exhibiting particular properties which can be used in high technology. These include shape memory alloys, piezoelectric materials, magnetorheological and electrorheological materials, magnetostrictive and chromic materials that change their color in reaction to various stimuli.

1.1. Piezoelectric composites

The piezoelectric element has both direct and inverse effects that enable its use as an actuator or a sensor. The direct effect is defined as the generation of an electric charge in proportion to an applied force, and the inverse effect induces an expansion or contraction under an applied electric field. Hence, a simplified ACLD configuration is developed with the benefit of the dual nature of the piezoelectric element as a self-sensing actuator [2, 18, 19]. Even though piezoelectric materials play a major role in achieving active damping in structures, they possess low control authority because their monolithic piezoelectric stress/strain constants are quite small in magnitude [20]. The fibers are subjected to a constant electric field in the direction transverse to the fiber direction, wherein the electric field is assumed to be the same for both the fibers and the matrix [14, 20]. Various micromechanics models were proposed to predict the effective properties of these PZCs from the properties of constituents [1]. One of the piezoelectric composites that are commercially available is Active Fiber Composites (AFC). These AFCs are composed of PZT fibers embedded in the epoxy matrix and sandwiched between two interdigitated electrodes as shown in Fig. 1.

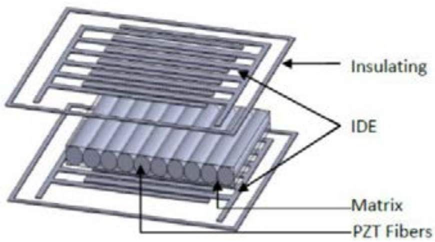

Fig. 1. Schematic presentations of Active Fiber Composites.

1.2. Active Constrained Layer Damped (ACLD)

The methods to overcome structural instability and to eliminate noise due to vibration include the isolation of the system from the source of vibration, redesign of the system, the attachment of masses, and the applications of damping treatments to the structure. There are distinctively two structural types of damping treatments, free-layer (unconstrained) and constrained layer damping (CLD) treatments. Free-layer damping treatments only refer to passive damping treatments, while CLD treatments consists of both passive and active damping treatments, also known as passive constrained layer damping (PCLD) and active constrained layer damping (ACLD), respectively. The Fig. 2 shows the methods of unconstrained layer damping, passive constrained layer damping (PCLD) and active constrained layer damping (ACLD).

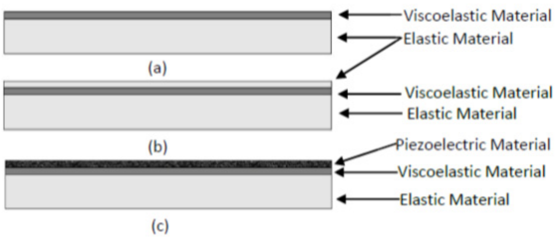

Fig. 2. Layer damping treatments: (a) free or unconstrained layer damping, (b) Passive constrained layer damping (PCLD), (c) Active constrained layer damping (ACLD).

PCLD treatments have been widely used to solve vibration problems in automotive, computer hardware, military, and aerospace industry [2]. These vibration solutions have led to many applications such as inlet guide vanes of jet engines, helicopter cabins, exhaust stacks, satellite structures, equipment panels, antenna structures, truss systems,

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