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ACLD of Smart Skew FFRC Plates Using 1-3 Piezoelectric Composites

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Abstract:- **This paper deals with the analysis of active constrained layer damping (ACLD) of smart skew fuzzy fiber reinforced composite (FFRC) plates. The novel constructional feature of this fuzzy fiber–reinforced composite is that the uniformly aligned carbon nanotubes (CNTs) are radially grown on the circumferential surface of the horizontal carbon fibers. The constraining layer of the ACLD treatment is composed of the vertically/obliquely reinforced 1-3 piezoelectric composites (PZC). A finite element model has been developed for accomplishing the task of the active constrained layer damping of skew fuzzy fiber reinforced composite (FFRC) plates integrated with the patches of such ACLD treatment. Both in-plane and out-of-plane actuations by the constraining layer of the ACLD treatment have been utilized for deriving the finite element model. The analysis revealed that the vertical actuation dominates over the in-plane actuation. Particular emphasis has been placed on investigating the performance of the patches when the orientation angle of the piezoelectric fibers of the constraining layer is varied in the two mutually orthogonal vertical planes. Also, the effects of varying the skew angle of the substrate composite plates and different boundary conditions on the performance of the patches have been studied. The analysis reveals that the vertically and the obliquely reinforced 1-3 PZC materials should be used for achieving the best control authority of the ACLD treatment according as the boundary conditions of the smart skew laminated composite plates are simply supported and clamped-clamped, respectively.**

Keywords:-- **Active constrained layer damping, skew Fuzzy Fiber–reinforced (FFRC) composites, Finite element model, 1-3 piezoelectric composite, skew actuator.**

I. INTRODUCTION

The schematic diagram illustrated in Fig. 1 represents a lamina of the FFRC containing wavy CNTs being studied here. The distinct constructional feature of such novel composite is that the wavy CNTs are radially grown on the circumferential surfaces of the unidirectional long carbon fiber reinforcements while they are uniformly spaced on the circumferential surface of the carbon fiber. Skew fuzzy fiber reinforced laminated composite plates shown in Fig. 2 are widely used in engineering applications such as aircraft wings, marine industries etc., and are highly prone to undergoing vibrations. Researchers extensively investigated the free vibrational characteristics of such skew plates [1-6]. In this paper, authors intend to investigate the active constrained layer damping (ACLD) of skew fuzzy fiber reinforced laminated composite plates. For such investigation, three dimensional analysis of ACLD of skew Fuzzy Fiber Reinforced laminated composite plates integrated with the patches of ACLD treatment has been carried out by the finite element method. The constraining layer of the ACLD treatment is considered to be made of the vertically or the obliquely reinforced 1-3 PZC materials. Particular emphasis has been placed on investigating the effect of variation of piezoelectric fiber orientation angle on the performance of the ACLD patches for controlling the vibrations of the skew fuzzy fiber reinforced laminated composite plates.

Finite Element Model of Smart Skew Fuzzy Fiber Reinforced Laminated Composite Plate

In this Section, FE model is developed for analyzing the ACLD of the laminated FFRC plates comprised of N number of laminae. Such laminated FFRC plate being integrated with the ACLD patches on its top surface is illustrated in Fig. 2. The constructional feature of the ACLD patches can be such that the piezoelectric fibers are coplanar with either the xz plane or the yz plane of the PZC layer. The piezoelectric fiber orientation in the PZC layer with respect to the z axis is denoted by ψ. The thickness of the PZC layer is h_p and that of the viscoelastic layer of the ACLD treatment is h_v. The middle plane of the substrate FFRC plate is considered as the reference plane. The origin of the laminate coordinate system (xyz) is located on the reference plane such way that the lines x=0,a and y=0,b represent the boundaries of the substrate plates. The thickness coordinates (z) of the top and the bottom surfaces of any (kth) layer of the overall plate are represented by $h_{(k+1)}$ and h_k (k=1,2,3,. . . ,N+2),

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respectively The final equations of motion governing the closed loop dynamics of the overall skew fuzzy fiber reinforced laminated composite plate/ACLD system can be obtained as follows:

$$[M]\{\ddot{X}\}+[K_{tt}]\{X\}+[K_{tr}]\{X_r\}+\sum_{j=1}^{m}k_d^j\{F_{tp}^j\}[U_t^j]\{\dot{X}\}+\sum_{j=1}^{m}k_d^j(h/2)\{F_{tp}^j\}[U_r^j]\{\dot{X}_r\}=\{F\}$$

$$[K_{tr}]^T\{X\}+[K_{rr}]\{X_r\}+\sum_{j=1}^{m}k_d^j\{F_{tp}^j\}[U_t^j]\{\dot{X}\}+\sum_{j=1}^{m}k_d^j(h/2)\{F_{tp}^j\}[U_r^j]\{\dot{X}_r\}=0$$

II. RESULTS AND DISCUSSION:

In this section, the numerical results obtained by the finite element model derived in the previous section have been presented. Symmetric cross-ply laminated skew fuzzy fiber reinforced substrate plates integrated with the two patches of ACLD treatment are considered for presenting the numerical results. . It should be noted that the locations of the ACLD patches correspond to an optimal placement of the ACLD treatment such that the energy dissipation corresponding to the first two modes becomes maximum (Ro and Baz, 2002). To analyze the damping characteristics of the laminated FFRC plates, the carbon fiber diameter and its volume fraction in the FFRC are taken as 10 µm and as 0.6, respectively. In order to investigate the damping characteristics of the skew laminated FFRC plates, frequency responses of the laminated FFRC plates integrated with the ACLD patches are investigated.

III. CONCLUSIONS:

In this paper, a study has been carried out to investigate the performance of the ACLD treatment for active damping of smart skew fuzzy fiber reinforced laminated composite plates when vertically/obliquely reinforced 1-3 PZC materials are used as the materials for the constraining layer of the ACLD treatment Fig.1. A three dimensional finite element model has been developed to describe the dynamics of the skew fuzzy fiber reinforced laminated composite plates integrated with the patches of ACLD treatment. Frequency response functions for the transverse displacement w (a/2, a/4cos□ , h/2) of a simply supported skew fuzzy fiber reinforced laminated symmetric cross-ply (0□ /90□ /0□) plate (a/h=100, ψ= 0□ , □ =30□) shown in Fig. 3. For the simply supported skew fuzzy fiber reinforced laminated substrate plates, the performance of the patches becomes maximum when the piezoelectric fiber orientation angle (ψ) is 0□ .

Fig. 4. illustrates the frequency responses for the transverse displacement of a point (a/2, b/4, h/2) of the SS symmetric cross-ply (0^o/[[90]]^o/0^o) base laminated plates (i.e., CNT volume fraction in the composite plate is zero, V_CNT=0) and skew laminated FFRC plates containing straight CNTs (ω=0). This figure display both controlled and uncontrolled frequency responses, and clearly reveal that the constraining layer made of the vertically reinforced 1–3 PZCs significantly attenuates the amplitude of vibrations and enhance the damping characteristics of the skew laminated FFRC plates over the passive damping (uncontrolled).

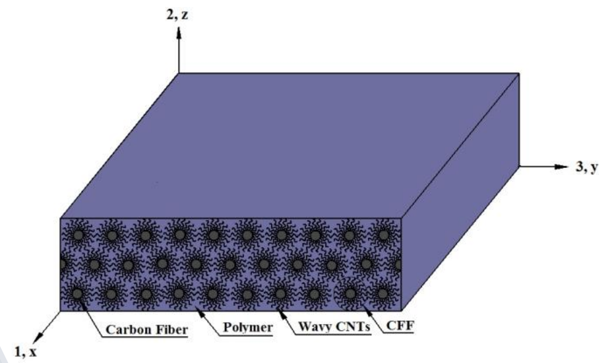

Fig. 1. Schematic diagram of a lamina made of the skew FFRC containing wavy CNTs.

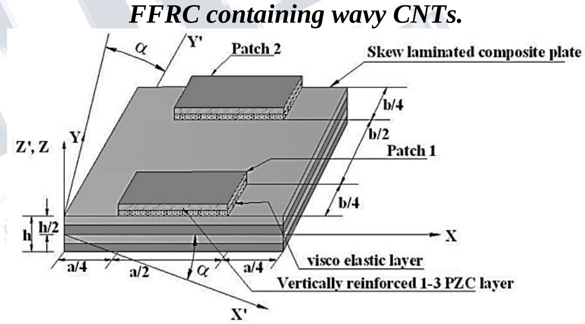

Fig. 2 Schematic representation of a skew fuzzy fiber reinforced laminated composite plate integrated with the patches of ACLD treatment composed of vertically/obliquely reinforced 1–3 piezoelectric composite constraining layer

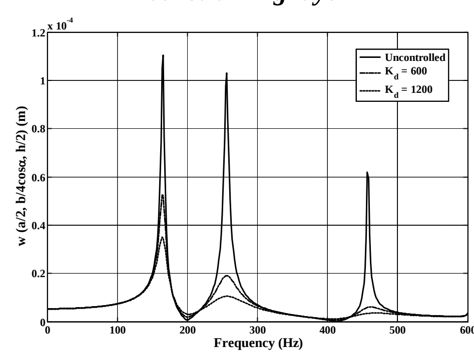

Fig. 3. Frequency response functions for the transverse displacement w (a/2, a/4cos□ , h/2) of a simply supported skew fuzzy fiber reinforced laminated symmetric cross-ply (0□ /90□ /0□) plate (a/h=100, ψ= 0□ , □ =30□).

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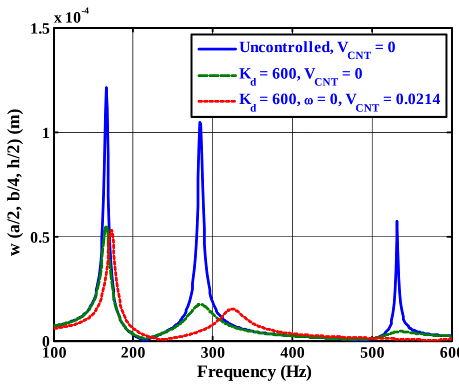

Fig. 4 Frequency responses for the transverse displacement (w) of the simply supported cross- ply (0^o/〖90〗^o/0^o) skew laminated plates (a/h=100, ψ= 0□ , □ =30□).

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