MFC

Dynamic Characteristics Modification of Damaged Composite Structure Using MFC and Active Control Algorithm

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Key Words : Active Control(), Laminated Composite(), Delamination(), Piezoelectric
Actuator(), Macro-fiber Composite Actuator(MFC)

ABSTRACT

In this work, active control algorithm is adopted to reduce delamination effects of the damaged composite structure and control performance with MFC actuator is numerically evaluated. Finite element model for the damaged composite structure with piezoelectric actuator is established based on improved layerwise theory. In order to achieve high control performance, MFC actuator, which has increased actuating force, is considered as a piezoelectric actuator. Mode shapes and corresponding natural frequencies for the damaged smart composite structure are studied. After design and implementation of active controller, dynamic characteristics of the damaged smart composite structure are investigated.

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carbon cyanate MFC

Table 1

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Table 2 Change of the natural frequencies

Mode	Healthy	Delaminated
1st	40.5 Hz	39.2 Hz
2nd	125.3 Hz	113.8 Hz
3rd	251.3 Hz	247.1 Hz
4th	432.9 Hz	406.8 Hz

가 $(i=1,2)^{(13)}$. (1)

1 $^{(10)}$.

$$\begin{aligned} \mathbf{M}\ddot{\mathbf{d}}_u + \mathbf{C}\dot{\mathbf{d}}_u + \mathbf{K}_{uu}\mathbf{d}_u + \mathbf{K}_{u\phi}\mathbf{d}_\phi &= \mathbf{F}_u \\ \mathbf{K}_{\phi u}\mathbf{d}_u + \mathbf{K}_{\phi\phi}\mathbf{d}_\phi &= \mathbf{F}_\phi \end{aligned} \quad (2)$$

(x,y,z)

$$\begin{aligned} U_1^k(x,y,z,t) &= u_1 + A_1^k(z)\phi_1 + B_1^k(z)w_{,x} \\ &\quad + \bar{C}_1^j(z)\bar{w}_{,x}^j + \sum_{j=1}^{N-1} \bar{u}_1^j H(z-z_j) \\ U_2^k(x,y,z,t) &= u_2 + A_2^k(z)\phi_2 + B_2^k(z)w_{,y} \\ &\quad + \bar{C}_2^j(z)\bar{w}_{,y}^j + \sum_{j=1}^{N-1} \bar{u}_2^j H(z-z_j) \\ U_3^k(x,y,z,t) &= w(x,y,t) \\ &\quad + \sum_{j=1}^{N-1} \bar{w}^j(x,y,t)H(z-z_j) \end{aligned} \quad (1)$$

U_1^k, U_2^k, U_3^k

u_1, u_2, w
 ϕ_1, ϕ_2
 x, y

$\bar{u}_1^j, \bar{u}_2^j, \bar{w}^j$ 가

z_j
 $H(z-z_j)$ heaviside unit step function

$A_i^k(z), B_i^k(z), \bar{C}_i^k(z)$

가

Fig. 1

(healthy structure) 가
(delaminated structure)

Fig. 2

가,
Table 2
가

가

Fig. 2 Mode shapes of the proposed composite structure

Ackermann

$$\mathbf{u} = -\mathbf{K}\mathbf{x} \tag{4}$$
$$\mathbf{K} = \begin{bmatrix} 0 & 0 & 0 & \cdots & \cdots & 1 \end{bmatrix} \begin{bmatrix} \mathbf{B} \\ \mathbf{A}\mathbf{B} \\ \mathbf{A}^2\mathbf{B} \\ \vdots \\ \vdots \\ \mathbf{A}^{n-1}\mathbf{B} \end{bmatrix} \phi(\mathbf{A}) \tag{5}$$
$$\begin{aligned} |s\mathbf{I} - (\mathbf{A} - \mathbf{B}\mathbf{K})| &= (s - \mu_1) \cdots (s - \mu_n) \\ &= s^n + \alpha_1 s^{n-1} + \alpha_2 s^{n-2} + \cdots + \alpha_{n-1} s + \alpha_n = 0 \end{aligned} \tag{6}$$
$$\phi(\mathbf{A}) = \mathbf{A}^n + \alpha_1 \mathbf{A}^{n-1} + \cdots + \alpha_{n-1} \mathbf{A} + \alpha_n \mathbf{I} \tag{7}$$

Fig. 3
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 , Table 2
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 Table 2
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Fig. 4

(2)

$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u} \tag{3}$$

(dashed line),
(dotted line),
(solid line)

$\mathbf{A}$, $\mathbf{B}$, $\mathbf{u}$ 가 , Table 2
가 ,
가 pole placement

Fig. 3 Pole locations for healthy and delaminated structure

Fig. 4 Frequency response: first mode excitation and first mode control

Fig. 5 Frequency response: first and third mode excitation, first and third mode control

(a) First four modes

(b) 1st mode

Fig. 6 Change of the pole locations

Fig. 7 Frequency response: from first to fourth mode excitation, first and third mode control

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Fig. 5

Fig. 6(a)

Fig. 6(b)

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Fig. 8 Control input histories

Table 3 Recovery of the natural frequencies

Mode	Healthy	Delaminated	Controlled
1st	40.5 Hz	39.2 Hz	40.5 Hz
2nd	125.3 Hz	113.8 Hz	113.8 Hz
3rd	251.3 Hz	247.1 Hz	251.3 Hz
4th	432.9 Hz	406.8 Hz	406.8 Hz

Fig. 7

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