論文の内容の要旨

論文題目　Damping characteristics of carbon-fiber reinforced composite laminates
(炭素繊維強化複合材料積層板の減衰特性)

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Fiber-reinforced composite laminates are increasingly used in many applications nowadays. For their use in the dynamic system, the dynamic response should be known. When damages occur, the elastic modulus seems to decrease but the damping properties tend to increase. However, it has not been proved to be correct for all composite laminates. Therefore, this paper studies the damping characteristics of composite laminates for both intact and cracked laminates.

The damping characteristics of T300/#3601 carbon-fiber reinforced composite laminates are studied in this work. The basic mechanical properties are obtained by using the static tensile test of $[0^\circ]_8$, $[90^\circ]_8$, and $[45^\circ_2/-45^\circ_2]$s laminates. The basic damping properties (the damping of the lamina), which are the loss factor based on strain energy component associated with normal stress in fiber and transverse direction (η_1 and η_2) and loss factor due to in-plane shear stress (η_{12}), as a function of frequency and strain energy amplitude are investigated by performing the free bending and free torsion vibration of cantilever beam of unidirectional laminates with end mass. The results of basic damping property measurements show that loss factor η_1 varies with both frequency and strain energy amplitude. On the other hand, loss factor η_2 and η_{12} depend on frequency but not on strain energy amplitude. The dependence of loss factor η_1 on the strain energy amplitude is due to the nonlinear effects. These three basic damping properties are used to predict the damping of the general types of symmetric laminates.

The damping of intact and cracked laminates is experimentally and analytically determined. The results of logarithmic decrement are obtained by performing the free bending vibration of cantilever beam with end mass. In the analysis, the energy approach is used to calculate the specific damping capacity (SDC) which is the ratio of the energy dissipation in one cycle to the maximum strain energy. The model of free bending vibration of cantilever beam with end mass is used to calculate stress and strain of intact laminates. To calculate the strain energy of the system, the stress and strain with the classical laminate plate theory is used. The $[0^\circ_2/90^\circ_2]$s, $[90^\circ_2/0^\circ_2]$s, and $[-45^\circ/90^\circ/45^\circ/0^\circ]$s laminates are used in this work. It can be seen that, for quasi-isotropic laminates, the analysis of free bending vibration with the consideration of coupling between bending and torsion mode has to be considered due to the existence of coupling arising from $\pm45^\circ$-ply. A very good correlation between analytical and experimental results of all intact laminates is obtained. It can be concluded that the damping of intact laminates at any frequency and strain energy amplitude can be correctly determined by using the basic damping properties as a function of frequency and strain energy amplitude.

The effect of transverse cracks is experimentally and analytically studied in the case of $[0^\circ_2/90^\circ_2]$s and $[90^\circ_2/0^\circ_2]$s laminates. The stress in cracked laminates is determined by variational solutions and finite element solutions. The analytical results are compared with the experimental results obtained from the free bending vibration of laminates with end mass. The experimental results show that the damping of $[0^{\circ}_{2}/90^{\circ}_{2}]$s laminates decreases with cracks. On the other hand, the damping of $[90^{\circ}_{2}/0^{\circ}_{2}]$s laminates increases with cracks.

The analytical results from both variational solutions and finite element solutions show that damping of cracked laminates decrease with cracks. Due to the mismatch between analytical and experimental results in the case of $[90^{\circ}_{2}/0^{\circ}_{2}]$s laminates, it can be concluded that not only the stress redistribution but also other effects may increase the damping of $[90^{\circ}_{2}/0^{\circ}_{2}]$s laminates.