CONSTRAINED LAYER DAMPING DUE TO IN-PLANE EXCITATION

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Introduction

Damping of constrained layer laminates (CLD) due to in-plane loading increases with the magnitude of the distortional strain energy induced in the constraining layer. For viscoelastic, constraining-layer materials with Poisson's ratios near 0.5, all strain energy is distortional. The constrained-layer strain energy and consequently the damping are strongly influenced by the orientation of the orthotropic constraining layers when subject to dynamic in-plane loads. CLD laminates with damping layers that have a Poisson's ratio less than 0.5 may have a maximum loss factor at constraining layer orientations less than 90° with respect to the applied load. Changes in geometry such as a free edge or an anomally such as ridge cause increased strain energy in the viscoleastic layers. The loss factor of constrained layer damped laminates with 3 different widths, found from impact hammer testing, demonstrate the effect of free-edges on damping. The results of a finite element analysis of constrained layer coupons further explain the damping caused by free-edges and geometric anomalies. In conclusion, the results of the analysis and testing demonstrate a pronounced increase in damping due to geometric anomalies.

Loss Factor of CLD due to In-Plane Forcing Function

The loss factor of a constrained layer laminate, η_c, is the energy lost per cycle, divided by the energy stored in each cycle. An acceptable method for approximating the loss factor of a CLD laminate is the modal strain energy method, MSE. It is assumed that the losses in the constrained layer are much greater than the losses in the constraining layer, so that damping consists of only the constrained layer losses. The composite loss factor, η_c, is thus approximated as the ratio of the dissipated distortional strain energy in the constrained layer to the total elastic strain energy in the laminate when it deforms in a particular undamped mode shape.

The loss factor for CLD laminate with multiple constraining layers with Poisson's ratios less than 0.5 loaded in the x-direction with

the maximum loss factors are plotted as a function of the viscoleastic Poisson's ratio and the ratio of lamina moduli in Fig. 1.

Figure 1 Constraining Layer at which the Maximum Loss Factor Occurs [θ/V/θ]

Effects of Free-Edges on Damping Due to In-plane Loading

Increasing damping of constrained layer laminates under uniaxial in-plane loading requires an increase in the distortional strain

a dynamic load may be computed as,

Effect of Constraining Layer Orientation on In-Plane Damping of a [θ/V/θ] Laminate

Using the expression shown in the previous section and the following properties,

$E_2=E_1/12$ $G_{12}=E_1/36$

$\nu_{12}=0.24$

energy in the damping layer by inducing significant transverse stresses. Increases in transverse stresses accompany a disruption in the in-plane stress field. The most common disruption arises due to a laminate boundary. The transverse stresses can become very large near a free-edge boundary. Finite element analysis and testing demonstrate the increase in damping due to free edges.

Table 1 Loss Factor for [θ/v/θ/v/θ] Laminate

θ	FEM w/ Edge Effects	CLT No Edge Effects
0º	$1.9(10^{-5})$	$0.9(10^{-5})$
30º	$1.4(10^{-2})$	$5.5(10^{-5})$

Table 1 shows the loss factors due to inplane dynamic loads when edge effects are included as calculated using the FEM and the loss factors when the edge effects are neglected.

Testing of CLD coupons was conducted using a Hewlett Packard 3560A dynamic signal analyzer connected to a piezoelectric accelerometer attached to the end of the test specimen. The specimen is impacted with a modally tuned hammer also connected to the signal analyzer. The specimens were suspended, tapped with the hammer and the frequency response trace was recorded. Three traces from each specimen were produced and analyzed and the loss factors calculated. Laminates of 16 plies with a $[20_4/V_2/-20_4/V_2/20_4]$ staking sequence were tested using AKZO Fortafil graphite-epoxy for the constraining layers. Five separate batches were cured and tested and the results are shown in Table 2. The loss factors of the 2 regions,(near the free edge where transverse stresses are present and the central region where only in-plane stresses are significant) are constant despite the coupon width. However, since the loss factor in the central region is predicted to be smaller than the loss factor near the free edge, the laminate loss factor should increase with diminishing coupon width. This is verified by the results in Table 2.

Table 2 Loss Factor Results from Impact Hammer Testing

	Width (cm)		
Batch	2.54	5.08	7.62
1	0.127	0.079	0.045
2	0.110	0.065	0.059
3	0.143	0.107	0.041
4	0.062	0.074	0.037
5	0.170	0.075	0.044
Avg.	0.122	0.080	0.045