DISCUSSION

J. E. Ruzicka[6] and T. F. Derby[7]

The authors have made a valuable contribution to the technical literature dealing with structural composites which incorporate viscoelastic shear-damping mechanisms. Of particular importance is the careful manner in which the various design parameters for constrained-layer damping have been independently evaluated experimentally.

There are, however, two considerations which require clarification. These are concerned with: (*a*) The prediction of composite structure damping D_c using the B_c^* route, and (*b*) the method employed to predict the static deflection of a three-layered symmetrical laminate.

Damping of Composite Structure

The authors' investigations of composite structure damping prediction techniques included selection of appropriate values of wavelength of flexural vibration (the λ route) and calculation of the complex flexural rigidity B_c^* using an iteration process (the B_c^* route). It was found that the λ route gave satisfactory results while the B_c^* route indicated theoretical values of composite structure damping that were 50 percent too small when compared to the measured values. The latter finding is contrary to what was found by the discussers and co-workers during a recent study, a portion of which was concerned with an evaluation of the B_c^* route for predicting composite structure damping.[8] In this investigation, it was found that excellent correlation existed between measured and theoretical values of damping. In particular, a linear regression analysis representing a least squares fit on $(D_c)_{\text{measured}}$ revealed the following:

$$(D_c)_{\text{measured}} = 0.001 + 1.05(D_c)_{\text{computed}}$$

which indicates that damping accountable from sources other than the constrained-layer damping mechanism is equivalent to an effective structure damping factor $D_c = 0.001$, and the structure damping factor is predicted only 5 percent too low on the average. These results would appear to establish the validity of the B_c^* route in predicting composite structure damping.

A comparison of the experimental and theoretical values of structure loss factor obtained by the discussers is shown in Fig. 18, where the loss factor η is equivalent to the authors' damping factor D_c. Data on this graph include 118 measurements for various free-free bending modes of 27 different beam specimens fabricated from various combinations of structural materials including aluminum, steel, and fibre-glass, with one type of viscoelastic damping material used for all specimens. The composite structural beam specimens included laminations of two solid sheets, a solid and a honeycomb sheet, two honeycomb sheets, a channel and flat sheet combination, and two channels oriented back-to-back.

Theoretical predictions were based on assuming that the effective flexural rigidity is the real part of the complex flexural rigidity as opposed to the authors' choice of using the absolute magnitude; however, this would account for only a small difference in theoretical prediction. Arbitrary values of frequency were selected to perform calculations of structure damping factor, with a continuous curve passed through these points to generate a prediction of damping factor versus frequency. Measured values of damping factor at various resonant frequencies were compared with the value indicated by the theoretical damping factor versus frequency curve for the various measured resonant frequencies of vibration. This comparison would seem to be equivalent to that made by the authors who first measured resonant frequency and then calculated a theoretical value of damping factor for that frequency. Hence, it is not clear why the authors find a lack of correlation between theory and experiment using the B_c^* route, especially since the authors and the discussers have used essentially the same method of calculation. Perhaps the authors could offer their views as to why opposite conclusions are being reached.

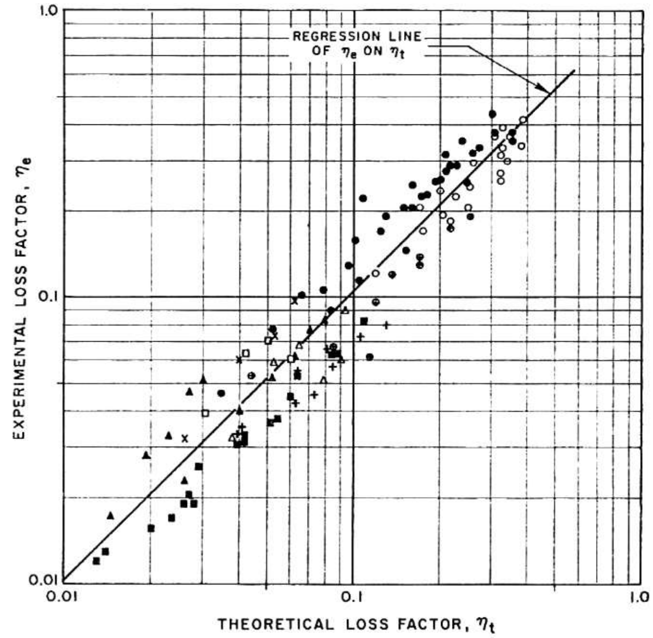

Fig. 18

Static Deflection

Using a relation provided by Dietz [10] the authors develop an expression for static deflection d_c of a centrally loaded simply supported beam in which the factor $(1 + c/e_{2s})$ appears where $c = 9H_cH_2/2L^2$ and $e_{2s} = E_{2s}/E_1$. While the comparison of measured and predicted static deflection presented by the authors is impressive, there would appear to be a limitation on the region of validity of the static deflection equation employed. For example, if the static modulus ratio e_{2s} approaches zero, the factor $(1 + c/e_{2s})$ approaches infinity rather than the appropriate value of 4.[8,9] Specifically, for viscoelastic shear-damping materials that are *very* soft compared to the stiffness of structural materials employed in the structural composite ($e_{2s} \rightarrow 0$), the factor $(1 + c/e_{2s})$ in the static deflection equation should become $(1 + Y)$, where Y is the geometrical parameter (having a value 3 for a three-layer symmetrical laminate). Another equation for static deflection is given by Dietz (equations (1–70) of reference [10] of the paper, appropriately changed to handle the simply supported case). This equation gives good results when compared to experimental results and also approaches the correct limiting value as the shear modulus of the core approaches zero. In cases checked by the discussers this equation was within a four percent error while the equation given by the authors was considerably in error (greater than 35 percent). For these cases the authors' factor of $(1 + c/e_{2s})$ was substantially larger than the upper limiting value of 4. Therefore, the circumstances under which the equation for static deflection presented by the authors is valid should be clarified.

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[8] J. E. Ruzicka, T. F. Derby, D. W. Schubert, and J. S. Pepi, "Damping of Structural Composites With Viscoelastic Shear-Damping Mechanisms," NASA Report CR-742, March, 1967.

[9] J. E. Ruzicka, "Vibration Response Characteristics of Viscoelastic-Damped Structures," *The Shock and Vibration Bulletin*, No. 34, Part 5, February, 1965, pp. 155–175.

Authors' Closure

We are grateful to Messrs. Ruzicka and Derby for their comments regarding the need for us to clarify the preceding two subjects, especially in light of their recent similar studies[8]; they also made the report available to us for detailed comparisons.

Damping of Composite Structure

The iterative procedures adopted by the two studies are equivalent; although the expressions for the effective flexural rigidity of composite beams appear to be different, they are numerically very similar for all values of D_2, X, and Y. Hence there is no computational disparity between the two procedures. This conclusion has been verified by a parallel set of calculations with the two procedures on a composite beam used by Ruzicka, et al. as the example in their report[8] [pp. 53–57 and Figs. 4.2 and 4.6 (C)].

		D_c (computed)	
f(cps)	X	This paper	Ruzicka, et al.[8]
10	3.07	0.105	0.107
50	1.37	0.201	0.202
100	0.95	0.256	0.258
1000	0.26	0.385	0.390

It has not been our intention to imply that the B_c^* route failed to correlate with the experimental results, even though the agreement appeared to be less quantitative than the corresponding predictions via the λ route. We feel that the results from the two studies should be considered to complement each other, which supports the conclusion that the equations developed for constrained-layer damping can be used, as a good approximation, to predict and optimize the performance of composite plates and beams.

Static Deflection

The present equation has been found valid up to $(9H_cH_2/2L^2e_{2,s}) = 2.75$ in our studies; for composite beams of practical dimensions, $e_{2,s}$ should be greater than 3×10^{-4}, as was true in all our samples reported in this paper. We are grateful to be reminded of this serious omission.

The approximate equation by Dietz was used as our starting point in order to attain a simple expression; his alternate route, which includes a series of expressions (equations (1–70) to (1–74) in reference [10]), is more vigorous and imposes no restraint on $e_{2,s}$; they also converge to the correct limiting expressions at $e_{2,s} = 0$ or unity. The latter route should be used for composites with viscoelastic materials of very low shear modulus as presently pointed out by Ruzicka and Derby.