DYNAMIC BEHAVIOR OF FLEXIBLE BEAMS WITH VISCOELASTIC LAYER TREATMENT

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Abstract. *Aerospace and aeronautical structures are classified as light and flexible ones, with low capacity of damping. In these particular structures, an efficient damping mechanism can be obtained by the placement of superficial viscoelastic layer treatment. When a material with viscoelastic behavior is integrated on the surface of the structure, a dissipating mechanism of the vibration energy transfer is introduced. Such treatment allows attenuation of undesired dynamic effects through a passive dynamic control without significant structural characteristics changes. Due to these factors, the superficial viscoelastic damping treatment is presented as a good alternative for the passive control of vibration on flexible and light structures. In this paper, an experimental study in order to evaluate the superficial viscoelastic damping treatment effects on the damping of flexible beams is conducted. The performance of a specific treatment in a constrained layer configuration on the dynamic behavior of the beams is characterized in terms of its modal parameters, including the natural frequency, damping ratio and mode shape, estimated by experimental modal analyses technique.*

Keywords*: damping, passive dynamic control, experimental modal analysis, viscoelastic layer treatment*

1. Introduction

Aircraft and sound rocket vehicles are examples of structures subject to severe vibratory environment. Under certain conditions, the imposition of external loads leads to very high resonant amplitudes at specific frequencies and in this case the damping plays an important hole in controlling the resonant response of these structures and prolonging their service life. Interested readers are referred to Nashif *et al*. (1985) and Harris (1996) for comprehensive literature of vibration damping and lists of references.

The viscoelastic layer damping treatments are an effective alternative for vibration passive control of structures and are widely used in the aeronautical and aerospace industry due their capacity of dissipating large amounts of energy when cycled loaded. This capacity is promoted by the long molecular chain interaction during loading.

The effects of these treatments in the vibration control of panels, plates and beams have been successfully investigated. Moreira and Rodrigues (1997) conducted experiments on free-layer surface damping treatments with viscoelastic layers applied on plates, in order to characterize the introduced damping and to evaluate the influence of viscoelastic layer thickness on the treatment effectiveness and on the related structural and dynamic characteristics modification. In another investigation, Moreira and Rodrigues (1998) presented an experimental study on integrated damping treatments with viscoelastic layers integrated on sandwich plates. Moreira and Rodrigues (2002) also used finite element commercial software to simulate the constrained and the integrated viscoelastic treatments applied on aluminum plates.

This work presents an experimental study of the effects of constrained viscoelastic treatment on the damping and natural frequencies of flexible beams. A set of three beams is evaluated. The reference specimen is an aluminum beam without any type of treatment. The two other beams are treated with a proprietary acrylic viscoelastic polymer with different thickness, covered by an aluminum layer. The dynamic behavior of the beams in the free-free condition is evaluated in terms of the natural frequencies, damping ratios and modal shapes, estimated by modal analysis.

2. Materials and Methods

2.1. Experimental Specimens

The beams were manufactured from 6061-T6 aluminum with the same dimensions (305x19.65x1.65 mm). The reference specimen, referenced as beam B1, is the beam without any type of damping treatment. The two others specimens, referenced as beam B2 and beam B3, are the beams treated with commercial viscoelastic layer damping (3M SJ 2015) with different thickness (0.13 mm and 0.50 mm respectively) on the constrained layer configuration, as shown in the Fig. 1. The constrained layer was obtained from a commercial aluminum tape (Promaflex Al 810 0.035 mm thick).

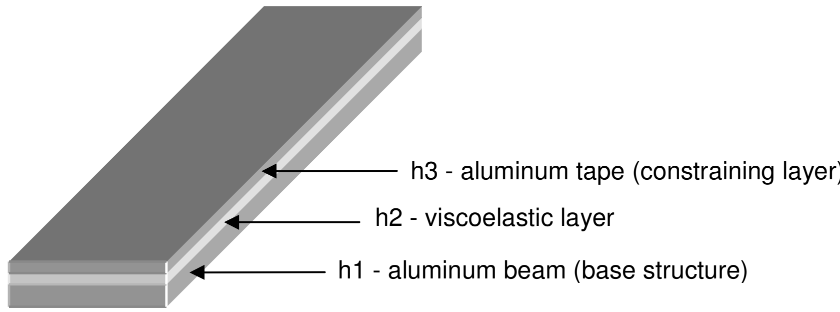


Figure 1. Experimental specimen on the constrained layer configuration

The characteristics of the specimens are described in Tab. 1.

Table 1. Characteristics of the specimens

Specimen	**Dimensions (mm)**			**Mass (g)**
	Length	**Width**	**Thickness h1 / h2 / h3**	
B1			1.65	25.65
B2	305	19.65	1.65 / 0.13 / 0.035	27.82
B3			1.65 / 0.50 / 0.035	28.04

2.2. Experimental Set-up

Modal tests were conducted to evaluate the effects of the constrained viscoelastic treatment on the modal parameters of the specimens. For this purpose, an experimental study was performed to provide some frequency response (FRF), measured on the specimens in a free-free condition. For the modal tests conducted, the excitation device used was the impact hammer, and the free response data were captured by an accelerometer and processed in order to obtain the FRFs. The surface of the specimen was discretized by eleven points, as shown in Fig. 2. We chose to fix the measuring point at point 1 and varied the forcing location along the capture points.

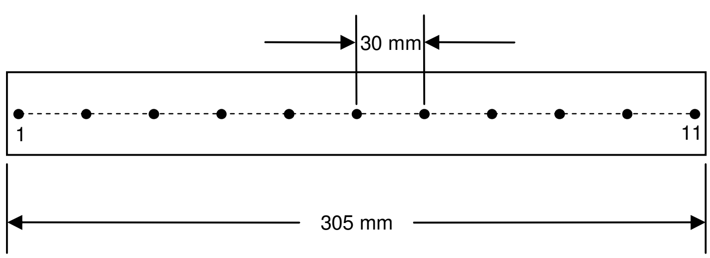


Figure 2. Capture points

The acceleration response was measured with a Brüel & Kjaer 4374 accelerometer and a Brüel & Kjaer 2626 signal conditioner. A PCB 086C03 impact hammer was employed for impulse excitation in each one of the eleven capture points.

The experimental set-up for each one of the beams is shown in Fig. 3. After the specimen has been supported and instrumented for the test, we averaged seven individual impulse force and response functions at each capture point.

Figure 3. Experimental set-up

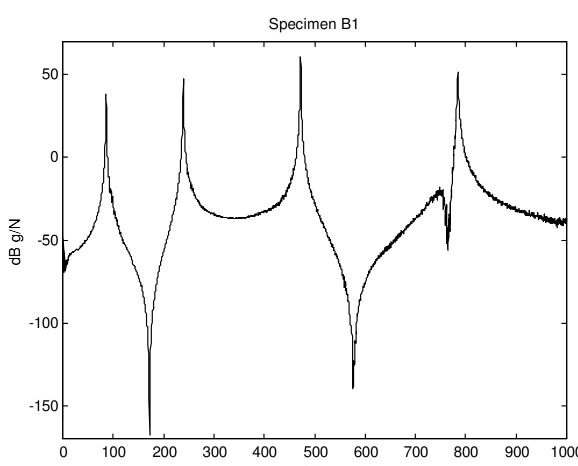
The signal processing parameters settled in the data acquisition system (VXI module Agilent E1432A 16 Channel 51.2 kSa/s Digitizer plus DSP, and Data Physics SignalCalc 620 Dynamic Signal Analyzer software) is described in Tab. 2.

Table 2. Signal processing parameters

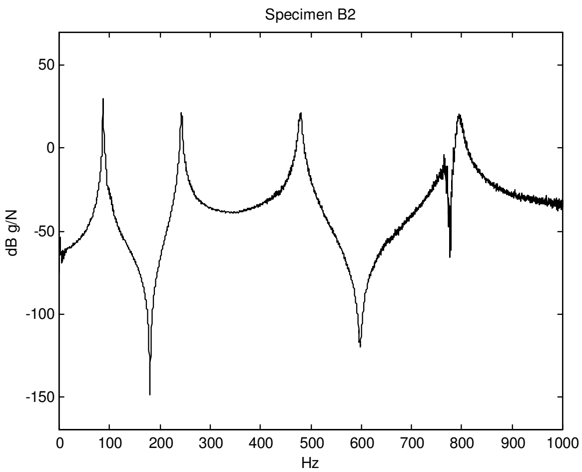
Parameters	**Configuration**
Analysis Frequency (Hz)	1000
Frequency resolution (Hz)	0.315
Average type	Stable
Number of averages	7
Spectral analysis window	Force / Exponential

3. Results and Discussions

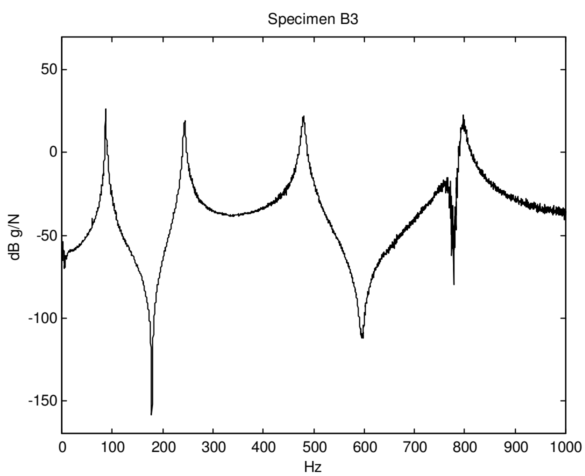
The first step in our experimental study of the effects of the damping treatments applied on aluminum flexible beams was the evaluation of the sets of FRFs acquired. Figure 4 illustrates the FRFs for the specimens B1, B2 and B3, estimated at point 7.



(a)



(b)



(c)

Figure 4. FRFs estimated at point 7. (a) Specimen B1. (b) Specimen B2. (c) Specimen B3

The consistency of the sets of FRFs acquired in 0 Hz to 1000 Hz frequency range was verified for each capture point and the general shape of the FRF curves estimated for each specimen exhibit similar dynamic behavior.

The modal parameters, including natural frequencies, damping factors and mode shapes, were estimated by the modal analysis commercial software LMS CADA-PC (LMS, 1994), using the maximum quadrature method (Maia and Silva, 1997), which is a single-degree-of-freedom method in the frequency domain.

The modal parameters are listed in Tab. 3 and the mode shapes are illustrated in Fig. 5. As the mode shapes obtained for each one of the beams are very similar, we chose to show only the mode shapes of specimen B1.

Table 3. Natural frequencies and damping ratios

Specimen	1st mode		2nd mode		3rd mode		4th mode	
	Natural Freq. (Hz)	**Damping Ratio (%)**	**Natural Freq. (Hz)**	**Damping Ratio (%)**	**Natural Freq. (Hz)**	**Damping Ratio (%)**	**Natural Freq. (Hz)**	**Damping Ratio (%)**
B1	85.98	0.44	239.42	0.24	473.58	0.16	786.88	0.08
B2	87.81	0.51	243.76	0.63	480.25	0.54	796.26	0.41
B3	87.41	0.75	244.07	0.73	479.55	0.65	795.88	0.64

Inspecting the modal parameters in Tab. 3, we observe that the effectiveness of the treatment on the damping ratio is more effective in higher modes and increases with a thicker viscoelastic layer. We also observe that the additional mass introduced (2.39 g for specimen B2 and 2.17 g for B3) does not lead to significant shifts on the natural frequencies (lower than 2%).

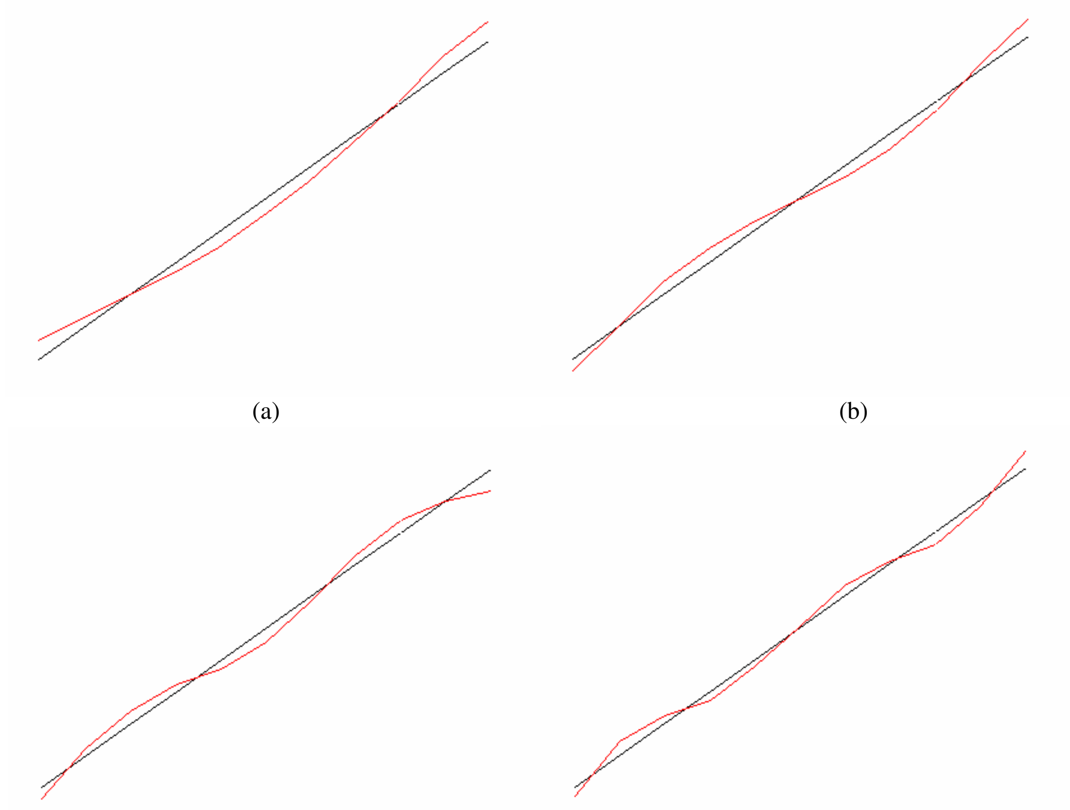


Figure 5. Mode shapes of specimen B1. (a) 1st mode. (b) 2nd mode. (c) 3rd mode. (d) 4th mode

4. Conclusions

In this paper the effectiveness of a superficial viscoelastic damping treatment on the dynamic behavior of flexible beams was investigated. A specific treatment in a constrained layer configuration was evaluated in an experimental study and provided a good alternative for the passive control of vibration of flexible beams, mainly on the higher modes, without representative structural characteristics changes. The experimental results obtained indicated that such treatment can be employed as an efficient damping mechanism on flexible and light structures.

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