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Passive Constrained Layer Damping: A State of the Art Review

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Passive Constrained Layer Damping: A State of the Art Review

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Abstract. In this paper authors discuss the advancements made over years in the passive constrained layer damping (PCLD) technique used for structural vibration control. To start with, the paper presents a brief literature survey on passive damping techniques using viscoelastic materials (VEM) emphasizing unconstrained layer damping (UCLD) followed by PCLD. The discussion on PCLD technique includes different mathematical models and experimental investigations related to it. Finally, the various design modifications proposed by the different researchers in order to improve the performance of conventional PCLD configuration in presented.

1. Introduction

Viscoelastic materials possess the inherent property of dissipating energy under a transient deformation. Based on this property, viscoelastic materials have long been utilized for suppression of structural vibrations. Generally, these materials are used in the form of a layer that is either freely attached to the surface of a host structure or constrained between a constraining layer and the host structure-surface. These two kinds of arrangements of a viscoelastic layer for passive damping of structural vibration are commonly known as UCLD and constrained layer damping (CLD). In some references, a CLD is also called as PCLD. The energy dissipation in a UCLD treatment occurs mainly due to alternate extension and compression of the viscoelastic layer, while the same in the CLD/PCLD treatment appears due to the transverse shear strains of the constrained viscoelastic layer. [1].

In this paper, at the outset, a brief introduction on passive damping technique using VEM is presented. Discussion starts with UCLD arrangement followed by PCLD arrangement. The research works related to PCLD arrangement is presented exhaustively mainly emphasizing its mathematical models, experimental investigations and design modifications in the conventional PCLD arrangement.

2. Passive Damping of Structural Vibration

In many common structural vibration applications where cost is a prime factor along with reliability, passive damping serves as the vibration control mechanism, and it is usually achieved by the use of viscoelastic materials. Several techniques in the use of viscoelastic materials for suppression of structural vibration have been proposed in the literature such as vibration absorbers, UCLD treatment or free layer damping, CLD treatment, tuned damper, edge damping etc. [2,3]. Among these various techniques, the UCLD and CLD treatments are the popular ones for control for bending mode of vibration of thin-walled flexible structures. In the following section, the damping mechanism, as well as a literature review on UCLD techniques, is presented.

2.1. Unconstrained Layer Damping (UCLD) Treatment
In the UCLD treatment, a viscoelastic layer is freely attached to the surface of a flexible structure (substrate layer) as shown in Figure 1. As the overall structure undergoes bending deformation, the viscoelastic layer experiences extensional/compressional strain (Figure 1) that leads to the energy-dissipation from the overall structure. This damping treatment was proposed in 1952 [4], and has been utilized substantially for passive damping of vibration of different engineering structures.
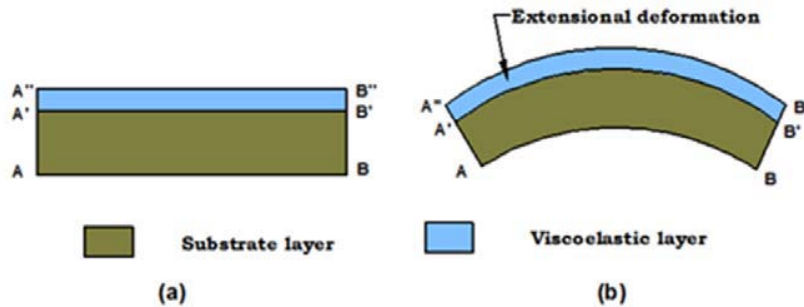

Figure 1. Schematic diagrams of (a) un-deformed and (b) deformed substrate layer integrated with a UCLD layer.

3. Passive Constrained Layer Damping (PCLD) Treatment
Although the UCLD treatment is easy to implement and also economically cheap passive damping arrangement, it possesses very low damping capacity that limits its applications in the suppression of structural vibration. In comparison to the UCLD treatment, a better passive damping treatment is the PCLD treatment [5, 6]. This damping treatment is found to be very useful in automobile and aircraft engineering applications especially for door panels, floor panels, dash panels, brake covers, skin, stringers, frames of fuselage section in commercial aircraft, flutter suppression of aeronautical panels. The damping (PCLD) treatment is also applied substantially in railway wheels, outlet guide van, computer hardware industry, squeal noise in trams, machine tool, spinning disks compression blades [7-14] etc.

A typical geometric configuration of the PCLD treatment is shown in Figure 2 where a viscoelastic layer is constrained between the surface of the host structure and a stiff constraining layer. As the overall structure undergoes bending deformation (Figure 2), the viscoelastic layer experiences transverse shear deformation/strain that leads to the energy-dissipation from the overall structure during its vibration.
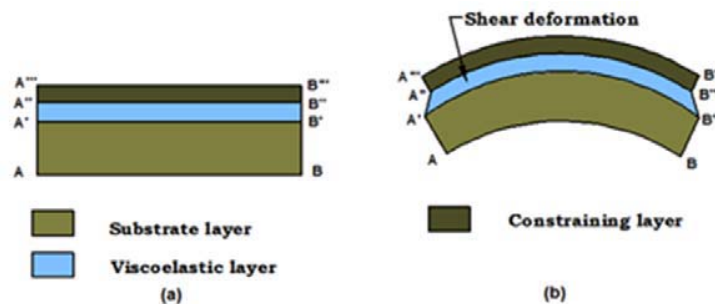

Figure 2. Schematic diagrams of (a) undeformed and (b) deformed substrate layer integrated with a PCLD layer.

The PCLD/CLD treatment was first introduced by Swallow [5] and its first mathematical formulation was addressed by Kerwin [6] considering travelling sinusoidal waves of transverse

displacements in beams. Afterward, various theoretical and experimental studies on the PCLD treatment of structures appeared in the literature particularly for investigating its damping mechanisms and damping capacity for different kinds of structures. The various mathematical models (FE and analytical) and their experimental verification related to PCLD are reported in the literature [15-35].

In most of the analyses of the PCLD/CLD treatment, extensional/compressional strains of the viscoelastic layer are not accounted for characterizing the passive damping since the damping appears mostly due to the shear strain of the damping layer [36]. However, it has also been shown in various studies that the compressional damping cannot be neglected especially for the damping treatment with a thick viscoelastic layer [37-41].

3.1. CLD/PCLD Treatment in Different Configurations

In the quest of improved damping capacity of the CLD/PCLD treatment, it (CLD/PCLD) appeared with different geometric and/or material configurations. One such effort to increase the damping is the introduction of segmented PCLD arrangement which was achieved by cutting the constraining layer to the appropriate lengths followed by its optimization. [42-46]. Apart from the segmentation of constraining layer, multilayer CLD configurations were also proposed [47-52]. Whittier [53] introduced a standoff/spacer layer between the damping layer and the surface of host structure for improved damping in the CLD treatment. The standoff layer enhances the shear strain in the constrained viscoelastic layer, and that results in the improved damping capacity of the CLD treatment. It was further modified and verified in many of the works. [54-56].

In some of the works viscoelastic composite material (VCM) layers in place of VEM have been proposed in order to increase the extensional as well as shear damping efficiency of the conventional PCLD treatment [57-59].

In many engineering designs of vibrating structural elements, the constraints of mass and economic cost of the overall structure are imposed. In this circumstance, partial PCLD treatment may be an obvious choice, and hence several works have been carried out on this aspect [60-72].

4. Conclusion

A literature review is presented with an objective of understanding the state-of-art research in the broad area of structural vibration control using PCLD arrangement. This literature survey reveals a substantial number of research reports on the passive damping of structural vibration using the viscoelastic materials in layer-form through CLD/PCLD arrangement. In these studies on the CLD treatment, the mathematical modeling and experimental verification of damping in the treatment have been ad-dressed for different kinds of structures. Along with these theoretical and experimental studies, the research in the quest of improved damping capacity of the CLD treatment has also been reported using standoff/spacer layer, segmented constraining layer, segmented damping layer, multiple damping layers, viscoelastic composite layers, partial PCLD closely spaced axial beams through VE layer, etc.

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