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Chapter 6

Viscoelastic damping treatments

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Abstract

Passive damping treatments using *viscoelastic materials* (VEM) represent a common and valuable solution for vibration control of light and thin structures. The introduction of thin layers of polymeric-based materials with the ability to dissipate deformation energy as heat has been broadly explored through the form of surface damping treatments, that can be applied onto panels and beams. This chapter aims to provide a comprehensive overview on the most important passive vibration control techniques for large, lightweight structures. Among these passive control techniques, a complete description is presented for viscoelastic damping treatments, which represent a significant segment of the passive damping treatments applied to light metallic and composite components. The main issues on viscoelastic material characterization and modeling, finite element simulation, and experimental analysis are discussed. The design and optimization of viscoelastic damping treatments are also addressed, and the most important optimal design rules are presented. Finally, the most significant trends for these damping mechanisms are discussed.

6.1 Introduction

Structural engineering has been constantly assisted by the development of new materials and improved production and assembly processes. During the last decades, new and improved materials, ranging from metallic alloys to high strength composite materials, have been used in the construction of structures that could not have been produced without these resources. Also, the use of fast and reliable simulation tools has encouraged designers to pursue new and challenging ideas, with an optimized balance between weight and stiffness.

The use of composites in the naval industry is simply one example of the evolution of structural engineering. In fact, the use of improved materials, specially taking advantage of sandwich structures, has made possible to construct lighter and stiffer vessels, when compared to the old ships made of timber. However, this evolution has some negative aspects. The most important one is related to the loss of inherent material damping when compared to old materials like cast iron, brass, or wood. Furthermore, new assembly processes, based on welding and stiff adhesives, have been responsible for the reduction of important dissipation mechanisms that were formerly incorporated through the use of nailed, riveted, and bolted connections, responsible for a significant part of damping due to the dissipation mechanisms developed within the interface between the connected parts. Therefore, use of lighter and stiffer materials with negligible material damping and elimination of mechanical connections demand the addition of damping sources to recover the beneficial effect of the lost dissipation mechanisms.

Damping may result as a natural consequence of an added material or device when subjected to the vibration field. This kind of damping treatment is therefore called passive damping treatment. Viscoelastic damping treatments, viscous dampers, and piezo-shunt devices are the most effective passive damping mechanisms.

Another form of damping can be achieved by active devices that counter the vibratory motion of the structure or change actively the damping properties. Piezoelectric materials, electro and magnetorheologic fluids, and shape memory alloys and polymers are effective materials for active damping. These materials and devices have the ability to change some physical or material property as a consequence of a variation of a strain, electrical, magnetic, or thermal field. Active devices add the controllability benefit but rely on complex control systems and require external power supply. See Section 5.3.2.

To combine the advantages of both passive and active vibration control systems, and to simultaneously remove or minimize the effect of their limitations, passive devices are often combined with active mechanisms. This combination is often designated as hybrid damping. Layered combinations of viscoelastic patches with piezoelectric constraining layers are just one example of this symbiotic association between materials exhibiting excellent damping characteristics with controllable response.

6.2 Viscoelastic damping treatments

Viscoelastic damping treatments are based on the addition of layers made of viscoelastic materials exhibiting significant material damping within the frequency and temperature range of interest. The layers can be inserted following different placement strategies. The viscoelastic patches can be simply placed over the entire surface of the structure, possibly covered by a stiff and thin layer of metal or polymer, or even embedded within the structure.

The damping mechanism obtained with this strategy results from the ability of these materials to convert the strain energy imparted to the VEM layer, by the cyclic deformation imposed by the adjacent vibrating structure, into heat that is dissipated to the surrounding medium. Therefore, the efficiency of these damping treatments depends directly on the amount of deformation that is imposed to the VEM layer and the percentage of energy loss that the material can dissipate. While the later depends solely on material characteristics, the former is a consequence of material modulus and location of the VEM layer on the final assembly. In fact, depending on the location of the VEM layer, it may be mainly deformed in shear or in extension.

Basically, the VEM layer can be positioned following two placement strategies: unconstrained layer (UCLD, also called FLD), and constrained layer (CLD) (Figure 5.9). A special form of the constrained configuration is obtained when the host structure is completely replaced by a symmetric sandwich arrangement with a viscoelastic layer core inserted between two skins with the same or similar thickness. While CLD and UCLD are considered treatments to be applied onto the finished structure, in the integrated layer damping configuration (ILD), the VEM core has to be inserted in the raw material during manufacturing (Figure 6.1).

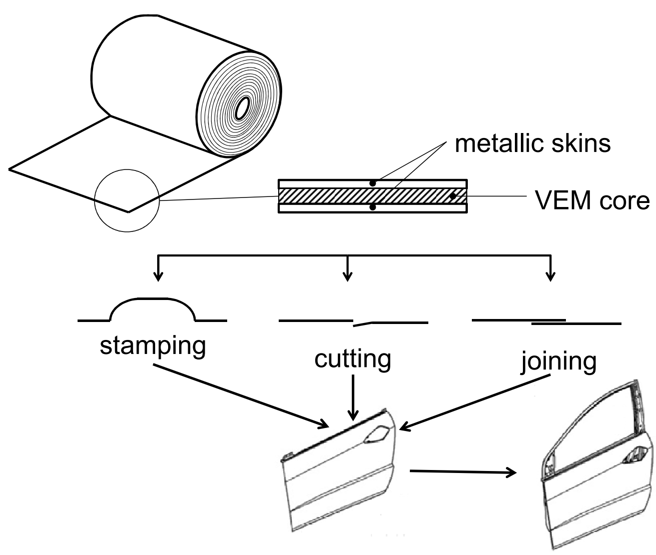

Figure 6.1: Metal sheet with integrated layer damping.

6.2.1 Unconstrained layer damping treatments

Unconstrained layer damping is obtained when the VEM layer is bonded on the surface of the host structure (Figure 5.9(a)). In this configuration, the VEM layer is mainly deformed in extension and requires thick layers to be effective. As a result, these treatments are usually not cost effective and introduce considerable mass, which limits their range of application. Conventional uses of UCLD include household appliances and automobile panels.