Available online at www.sciencedirect.com
ScienceDirect
Computers and Structures 86 (2008) 437–446
Computers & Structures
www.elsevier.com/locate/compstruc

Transmissibility characteristics of stiffened profiles for designed-in viscoelastic damping pockets in beams

Nigel D. Butler, S. Olutunde Oyadiji *

School of Mechanical, Aerospace and Civil Engineering, University of Manchester, Manchester M13 9PL, United Kingdom

Available online 16 April 2007

Abstract

It has been show in previous work that the levels of damping produced by these designed-in viscoelastic damping pockets (VDP's) can be greater than that of a traditional CLD treatment, but the loss in structural stiffness can be most undesirable. In this work, the use of different shaped damping pockets which produce webs and structural stiffeners running along the length of the beam are investigated using the finite element method. It is shown that the introduction of the stiffening profiles greatly reduces the loss in structural stiffness, and the levels of damping achieved by the designed-in damping is still substantial.
© 2007 Elsevier Ltd. All rights reserved.

Keywords: Viscoelastic; Damping; Constrained layer dampers (CLD); Damping pockets; Stiffening profiles; Sandwich beams

1. Introduction

There is an increasing demand for structures and systems in aerospace, automotive and civil engineering to become increasingly lighter to increase performance. However this reduction in weight can often make the components susceptible to vibration problems. Not only can vibration cause unwanted noise, but it is also a major factor in cyclic fatigue damage to components, which can lead to cracking and even failure. One way to minimise vibration is to introduce damping into the structure. Damping is the mechanism by which the vibrational energy of a structure is dissipated as heat causing the amplitude of vibration of the structure to be reduced.

It is well known that constrained layer dampers (CLD's) can offer an effective means for suppressing structural vibration. Research into CLD's and their performance as damping materials began in the 1960s and there have been many papers written in this field. Early works looked into the use of CLD's as passive damping treatments (PCLD). Mead and Markus [1] and DiTaranto [2] looked at the vibration of sandwich beams. In addition, different formulations and techniques for modeling and predicting the energy dissipation of the viscoelastic core layer have been reported [3–5]. The complexity of these were increased, looking at effects such as inclusion of thickness deformation of the core layer in the model [6] and looking at cases where only a portion of the base structure is covered by PCLD treatment [7].

Finite element analysis has also been used in the modeling of constrained layer damping since the 1970's [8,9] and by 1990's researchers had started looking at making CLD's which were active (ACLD). Here an active element, such as a piezoelectric layer, is used to replace, or in conjunction with, the passive constraining layer, thereby enhancing the energy dissipation of the damping treatment by increasing the deformation of the core. Several analytical formulations of ACLD treatments were proposed by Baz and Ro [10], and Shen [11]. Baz derived a sixth order ordinary differential equation governing the bending vibratory motion and the vibration control of an Euler–Bernoulli beam with full and partial ACLD treatment, while Shen's mathematical formulation addresses the coupling nature of the bending and axial motions of an Euler–Bernoulli beam with ACLD treatments.

* Corresponding author.
E-mail address: s.o.oyadiji@manchester.ac.uk (S.O. Oyadiji).

0045-7949/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compstruc.2007.02.003

There has also been much work done to optimise these damping treatments. This includes maximising the modal strain energies by determining the optimal materials to use and geometric parameters of the treatments, such as location and size. The aim is to minimise the weight added to the structure and cost by reducing the amounts of material used. Baz and Ro [10] used the Univariate Search Method to optimise ACLD treatments by selecting the optimal thickness and shear modulus of the viscoelastic layer, and Marcelin et al. [12,13] used a genetic algorithm method and finite element to maximise the loss factor for a partially treated beam by altering the dimensions and locations of the treatment patches. As verified by Nokes and Nelson [14], this layout optimisation of CLD patches can lead to a significant saving in the amount of ACLD material used.

In order to get the maximum levels of damping, the CLD must be bonded to a smooth surface. Rough or jagged surfaces can be very difficult or impossible to apply the damping treatment to. Sometimes this can be overcome by using a thicker viscoelastic layer. This can be used for slightly rough surfaces, as the thickness of the polymer compensates for the roughness of the surface. Not only does this increase the cost of the treatment, but also reduces its performance as the levels of shear deformation within a thicker viscoelastic layer are lower. Sun and Tong [15], and Kung and Singh [16] have looked at the effects of debonding and incomplete coverage of the viscoelastic layer on the base structure and show that as the level of coverage is reduced the levels of damping achieved are also lowered from both passive and active CLD treatments.

Further work has also been done looking into the use of viscoelastic materials in laminated composite plates. Nayfeh [17] developed a model for vibration parallel to the plane of lamination of a symmetric five-layer elastic–viscoelastic sandwich beam. The model is used to study the resonant frequencies and damping ratios of the lowest several modes of beams with various boundary conditions and inertia and stiffness properties as the shear stiffnesses of the viscoelastic layers are varied. Teng and Hu [18] looked at the design parameters for constrained layer damping treatments and laminated beams by employing the Ross–Kerwin–Ungar (RKU) model. They also discussed effects of temperature, frequency and the dimensions of damped structures on vibration damping characteristics. As well as laminated composites, work has been done on the effects of adding materials to the viscoelastic layer. For example Alberts and Xia [19] looked at a viscoelastic matrix which contains high elastic modulus fibers to improve the damping performance of the polymer, and Finegan and Gibson [20] looked at the improvement of damping at the micromechanical level in polymer composite materials under transverse normal loading by the use of special fiber coatings and reinforcing the polymer with coated fibers.

The approach adopted in the present work is the use of damping pockets in a structure. These are in the form of cavities filled with a viscoelastic material. These geometric features are designed-in or introduced into parts of the structure where there is significant strain such that the enclosed viscoelastic medium is subjected to significant levels of shear deformation. To illustrate the benefits of these designed-in damping treatments, the vibration response of viscoelastically-damped beams are predicted using the finite element method. A series of cantilevered beams are considered. This includes bare beams, beams with CLD treatments, and beams with thickness-wise slots filled with viscoelastic material. Previous work on designed-in viscoelastic damping treatments has looked at the damping effectiveness of slots, holes and cavities filled with viscoelastic material [21], and investigated varying the geometric parameters of the structure to maximise the levels of damping [22]. However the reduction in structural stiffness caused by introducing these treatments caused large shifts in the natural frequencies of the structure. In the current work the profiles of the beam are varied to try and reduce the loss in stiffness caused by introducing the damping treatment.

2. Advantages of using designed-in viscoelastic damping treatments

If a structure is excited at, or near, its natural frequency the levels of response generated can be large. There are only a small number of ways by which this can be overcome. Firstly, the mass and stiffness characteristics can be changed so that the natural frequency is outside the operating range. The problem with this approach is that it can lead to a dramatic increase in weight of the structure, which can have negative effects on the performance and efficiency. Secondly, the structure can be isolated from the source of the vibration, but this cannot always be done. The third option is to introduce damping into the structure so that vibrational energy is dissipated as heat. For many years viscoelastic materials have been applied to structures to add damping. Here the vibrational energy is dissipated when the viscoelastic material is deformed. By adding a stiff constraining layer to the viscoelastic material the levels of shear deformation are increased, and the damping performance in improved. However, it is not always possible to use one of these traditional damping methods on a structure. Several of these cases, and other advantages to using a designed-in viscoelastic damping treatment are highlighted below.

Surface finish critical – In applications where the surface finish or shape is critical, it is undesirable to apply a traditional CLD treatment to the structure, as this would alter the profile or affect its surface finish. By using designed-in damping the critical surface can remain unchanged.

Bad surface finish – Traditional CLD damping treatments can not always be used successfully where the surface finish is rough or jagged. If there is not enough of a bond between the structure and the viscoelastic layer,

Download English Version:

https://daneshyari.com/en/article/511099

Download Persian Version:

https://daneshyari.com/article/511099

Daneshyari.com