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A Survey on Active Constrained Layer Damping Treatment

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ABSTRACT: Vibration problems have received much attention in recent years. Passive methods, such as sound absorbing but in low frequent noise problems these passive methods may lead to an unacceptable increase of weight and volume materials give good results in reducing many vibration problems. In the survey the Active Constrained Layer Damping (ACLD) is investigated regarding the ability to increase the damping of the frequency of a beam by. In PCLD does not change its layer where in ACLD, change its patch and layer. The piezo patch increases the shear strain in the viscoelastic layer which increases the energy dissipation. This survey concludes with configuration setup how can used it.

Keywords: Active constrained layer damping, Passive constrained layer damping, Visco elastic material.

I. INTRODUCTION

Vibration problems exist for a long time. In recent years the many research in the field of vibration reduction and its control. The fact that vibration problems occur more often because of the lightweight designs and different causes. In industries, vibration causes such as machine metal cutting process machines noise etc. in machines, vibration causes such as nuts and other fasteners become loose[1]. So vibration is main problem in industries also aircraft, satellite etc.

The human being act as parts of the engineering system. Different effect of vibration on human such as discomfort and loss efficiency. So we need the reduced the vibration for better efficiency of system.

These are different ways increase the damping in system. Constrained layer damping (CLD) is one type treatment for increase damping system. This is a surface damping treatment. A layer of visco elastic material (VEM) is applied on the surface structure. A constraining layer is placed on the visco elastic material. Constrained layer is made of a non actuating material. This treatment is known Passive Constrained Layer Damping (PCLD)[2]. If we can uses piezo electrical materials as an actuator is mounted on the constraining layer. This treatment is known Active Constrained Layer Damping (ACLD) treatment. It is stability of system compare PCLD.

Figure 1. Constrained layer damping treatment

1.1 Passive Constrained Layer Damping:

PCLD is a surface damping treatment control the vibration. It is consists of one or more visco elastic layers and one or more non actuated CL. These PCLD treatments are mounted to a base layer. If the base layer is subject to bending, the VEM layer is constrained by the base layer and the CL, which causes the VEM layer to shear. This shear deformation causes the energy dissipation.

In CLD techniques there are many parameters that need to be chosen, for instance dimensions of the plates, materials etc. Optimization of the CLD is a complicated matter. But if the optimization is done correctly PCLD is a very good technique to add damping.

1.2 Active Constrained Layer Damping:

Active constrained layer damping is one type of constrained layer damping treatment for increase the damping in system. When the constrained layer in passive constrained layer damping techniques is replaced by piezoelectric layer it is called active constrained layer damping. The CL in PCLD techniques is replaced by or enhanced with actuators it is called ACLD.In this treatment piezo electric material used as a constrained layer. ACLD is described as a smart, failsafe and efficient vibration control method over a large frequency band.

There are two types of ACLD, direct and indirect (ACLDd and ACLDi respectively). With ACLDd the actuating piezo patch is bonded to the base plate by the VEM. With ACLDi the actuating piezo patch is bonded to the constraining layer, and the constraining layer is bonded to the base plate by a VEM layer. With both types of ACLD the shear strain in the VEM is increased and thus more energy can be dissipated.

Active constrained layer damping (ACLD) treatments have been successfully utilized as effective means for damping out vibration of various flexible structures like beams, frames, plates, shells and trusses.

II. CONFIGURATION OF ACLD TREATMET

The first configuration, figure (2), is based on the RKU model[4]. Theoretically this is possible but in practice it is very difficult to use a piezo patch for sensing and actuating at the same time especially because the actuating signal will be larger than the sensing signal. Therefore an additional sensor patch will be added. An advantage is that the actuator and sensor are collocated. Taking a separate sensor and actuator and keeping them collocated in length and width direction leads to the configuration as depicted in figure (3). This configuration has the advantage that the effect of the active control action on the base plate is measured directly on the base plate without a viscoelastic layer between sensor and plate. The third configuration is based on the model of Liu and Wang. As mentioned earlier it is not practical to incorporate sensing and actuating in one piezo patch. Another possibility with this configuration is using one piezo patch as actuator and the other as sensor. One major disadvantage of this configuration is that the sensor is unable to measure the vibration of the plate directly due to the viscoelastic layer. This makes it difficult to calculate the necessary control action. Moreover the object of placing a treatment on both sides of the base plate is to introduce symmetry in the setup, this symmetry is lost if the actuation only occurs on one side.

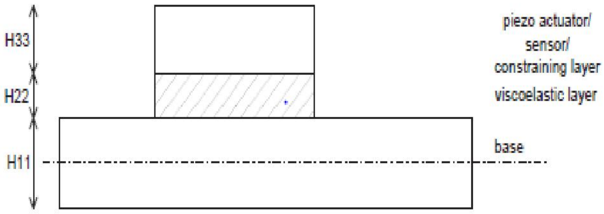

Figure 2. Configuration 1

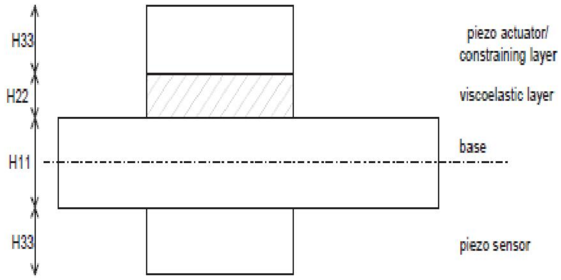

Figure 3. Configuration 2

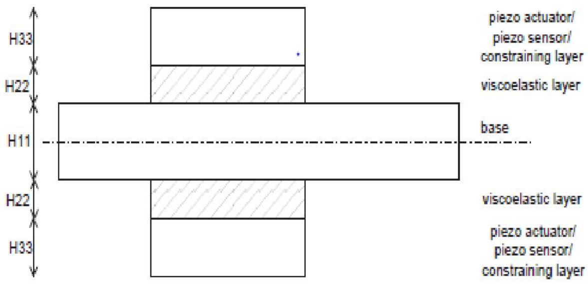

Figure 4. Configuration 3

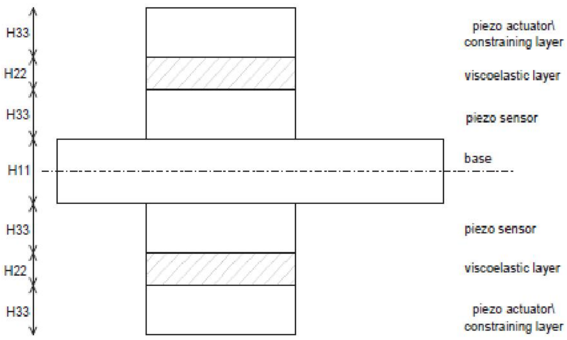

Figure 5. Configuration 4

With the last configuration, shown in figure (5), the treatment is symmetrical with sensing piezo patches directly mounted on the base plate and actuating piezo patches that are mounted on the sensing piezo patches with the visco elastic layer. A disadvantage of this configuration is that the sensing piezo patch is mounted between the actuating piezo patch and the base plate. As a consequence it remains to be seen whether the signal measured with this configuration is indeed the vibration of the plate or if it also consists of a part of the control action of the actuating piezo patch that is not transferred to the base plate. Therefore configuration 2, shown in figure (3), is chosen for the experiments [6]. In order to determine the optimal dimensions of the treatment an optimization routine is used to determine the thicknesses of the different layers.

This optimization routine is strictly speaking only for PCLD, but it gives a (coarse) estimate of the optimal thicknesses for all the layers. The choice of materials is determined by the fact that in an MRI scanner only non-magnetic materials can be used. The base plate is made of polystyrene. This material was chosen in order to be able to compare the results of the ACLD experiments with the results of the PCLD experiment. The PCLD experiment was conducted with polystyrene plates provided by Heathcote Industrial Plastics. These polystyrene plates have a visco elastic polymer sandwiched between them making it a PCLD treatment. The visco elastic layer is made of HIP2 visco elastic polymer, produced by Heathcoat Industrial Plastics. The piezo patches are made of PXE5 with silver electrodes.
The material properties are listed in table. The dimensions of the base plate are 0:211 m by 0:161 m.

***Table 1. Material properties of Polystyr*ene, PXE5 and HIP2**

parameter	value	symbol
Polystyrene		
modulus of elasticity $[\frac{N}{m^2}]$	$2.75\ 10^9$	E_p
density $[\frac{kg}{m^3}]$	$1.06\ 10^3$	ρ_p
poisson ratio [-]	0.4	ν_p
loss factor	0.001	η_p
length plate $[m]$	0.211	L
width plate $[m]$	0.161	b
thickness plate $[m]$	$2\ 10^{-3}$	t_p
PXE5		
thickness sensor [m]	$0.4\ 10^{-3}$	t_a
thickness actuator [m]	$1\ 10^{-3}$	t_{piezo}
length piezo patch[m]	$76\ 10^{-3}$	L
width piezo patch [m]	$45\ 10^{-3}$	b
modulus of elasticity $[\frac{N}{m^2}]$	$1.36\ 10^{11}$	E_{piezo}
poisson ratio [-]	0.3	ν_{piezo}
density $[\frac{kg}{m^3}]$	$7.8\ 10^3$	ρ_{piezo}
HIP2		
modulus of elasticity $[\frac{N}{m^2}]$	$5\ 10^6$	E_{vis}
shear modulus [ ]	$5\ 10^3$	G_{vis}
density $[\frac{kg}{m^3}]$	980	ρ_{vis}
poisson ratio [-]	0.49	ν_{vis}
loss factor [-]	0.9	η_{vis}
length HIP2$[m]$	$76\ 10^{-3}$	L
width HIP2 $[m]$	$45\ 10^{-3}$	b
thickness HIP2 $[m]$	$0.26\ 10^{-3}$	t

III. CHOICE OF DIMENSION OF ACLD TREATMENT

The dimensions of the piezo patches need to be less than half the wavelength of interest in order to be able to sense the mode correctly. In order to be able to look at at least the first two modes the dimensions of the piezo patches need to be less than 0:1055 m by 0:0805 m. A first (coarse) estimation of the optimal thicknesses of the visco elastic layer ($H2$) and the piezo patch ($H3$) can be obtained with the RKU model. This implies that the passive damping will be maximal for the calculated thicknesses. The RKU model is valid for configurations of the type as seen in figure (a) and (c), with rigid and visco elastic layers alternately. The RKU model is not valid for configurations with two normal or two visco elastic layers on top of each other like configuration 2 and 4. Using the RKU model will lead to an overestimation of the actual stiffness of the plate, because it assumes a treatment over the whole surface of the base plate. Another assumption in this model is the loss factor of the visco elastic layer, it is assumed to be 0:9.

The visco elastic material is available in two thicknesses 0:13 mm and 0:26 mm. From simulations with the two available thicknesses of the visco elastic layer it is obvious that the thicker layer gives more damping and thus only the visco elastic layer with a thickness of 0:26 mm is used. The piezo patches are available in the thicknesses 0:4 mm, 0:5 mm and 1 mm. The piezo patches are 76 mm long and 45 mm wide.

IV. EQUIPMENT FOR ACLD TREATMENT

The base plate is clamped in a box as shown in figure, which was fabricated at Philips. It is a thick-walled rectangular box of aluminum with two sides open. The walls are 30 mm thick. The top is closed with an aluminum plate of the same thickness as the rest of the box. The other open side is closed with the polystyrene base plate with or without the treatment. The polystyrene plate is 210 mm long, 160 mm wide and 2 mm thick[2]. The sensing and actuating piezo patches are 0:4 mm and 1 mm respectively.

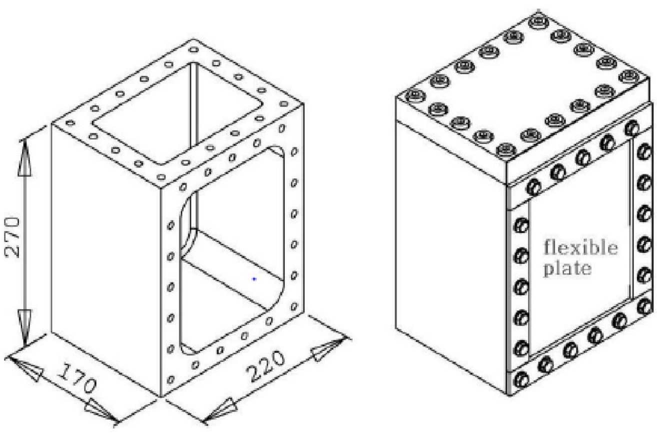

Figure 6. Drawing of the aluminum box

The disturbance is introduced to the system by a speaker inside the box. The signal to the speaker is generated within the siglab environment of matlab and sent to the speaker through Siglab and an amplifier of the type TPO25 from Ling Dynamical Systems. For the transfer function measurements the signal to the speaker is band-limited white noise from 1 Hz to 1 KHz. The actuating piezo patch is used to control the plate. In the control experiments the signal to the actuating piezo patch can be generated with matlab simulink and can be sent to the piezo patch with a Tu/e DAC and an external amplifier[7]. This amplifier is a TPO25. The TU/e DAQ measuring device has as a major disadvantage, it can only produce and measure a signal between ¡2:5 V and 2:5 V. So in order to get a higher voltage to the actuator the signal needs to be amplified and the sensor signal needs to be diminished. This is done by means of a resistance bridge.

V. APPLICATION AND ADAVANTAGES

1. Very high levels of damping compared to other damping methods.
2. Can be very weight efficient.
3. Easily applied to existing structures.
4. Satellite, jet rocket, aerospace.
5. Industrial application

VI. CONCLUSION

In this paper we survey the ACLD set-up is used for vibration control. The base plate with treatment is a four layer configuration with the sensing piezo patch directly mounted on the base plate and the actuating piezo patch mounted to the base plate with an visco elastic layer. The dimensions of the base plate are 210 by 160 by 2 mm and the length and width of the treatment are 76 and 45 mm respectively. The thickness of the visco elastic layer is 0:26mmand the sensing piezo patch and the actuating piezo patch are 0:4 and 1mmthick. The piezo patches have a strip of copper foil attached to them to ensure a thin conducting film between the piezo patches and the layers they are attached to. The wires are soldered to the copper foil.

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