FIFTH INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
DECEMBER 15-18, 1997
ADELAIDE, SOUTH AUSTRALIA
Invited Paper

ACTIVE CONSTRAINED LAYER DAMPING ON CYLINDRICAL SHELLS

Kam W. Ng

Office of Naval Research
Arlington, VA 22217-5660, USA

ABSTRACT

Vibration of finite cylindrical shell was controlled using active constrained layer damping technique. Specifically, three damping patch configurations at various locations were tested and evaluated. Results showed that the damping patches bonded on the end cap are more effective than the damping patches bonded to the free end of the cylinder. Performance of the damping patches depends on the size and shape of the patch. Overall results showed that the active constrained layer is viable and has greater vibration suppression than the passive constrained layer damping.

INTRODUCTION

Active constrained layer damping technique has been developed [1] to control vibration in beams and plates. As shown in Fig. 1, visco-elastic damping layer is sandwiched between two piezo-electric layers to provide built-in sensing and control capabilities that actively tune the shear of the visco-elastic layer, in response to the structural vibrations. The sensing, as indicated by the sensor voltage V_s, is provided by the piezo-electric layer which is directly bonded to the structure. The actuation is generated by the other piezo-electric layer which acts as an active constrained layer that is activated by the control voltage V_c.

The objective of this experimental study was to quantify the performance of several active constrained layer damping configurations in controlling vibration of finite cylindrical shells. Specifically, multiple triangular and multiple rectangular damping patches were tested and evaluated. In addition, single and combination of two or more patches were also investigated.

DESCRIPTION OF THE EXPERIMENT

The test cylinder is made of aluminum (20 cm diameter, 30 cm long and 0.5 mm thick) with 0.13 mm thick end cap. The three active constrained layer damping configurations considered in this experimental study are shown in Fig. 2 which include: a) six triangular patches (10 cm wide, 5 cm high) bonded to the free end of the cylinder, b) four rectangular patches (1.3 cm x 5.7 cm) bonded to the end cap, and c) four rectangular patches (2.5 cm x 8.3 cm) bonded to the end cap. The visco-elastic layer is 0.5 mm thick DYAD-606 from SOUNDCOAT and the piezo-electric layers are made from PVDF polymeric films from AMP, Inc.

The end cap of the cylinder was excited by a speaker driven by sinusoidal or white noise source. The signal from the sensor was amplified and feedback to the active constrained layer using simple proportional control law via an analog circuit.

RESULTS AND DISCUSSION

The cylinder wall and end cap were excited by a 30 cm diameter speaker located 4 cm from the end cap using sinusoidal or broadband (white) noise source. One of the piezo-electric layers that served as the sensor was used to monitor the vibration of the shell.

The dominant structural modes of the cylinder wall are 26, 72.5. 107.5 and 146 Hz. Six triangular damping patches were placed in equal spacing on the free end of the cylinder (see Fig. 2a). Accordingly, one or multiple patches could be selected and used to suppress the symmetric and asymmetric modes. Results showed a single patch can attenuate 2.3 to 2.8 dB of the first mode, i.e., 26 Hz, with control voltage (V_c) of 1 to 5 V. It was observed that attenuation increases with increasing V_c. Using two patches, the attenuation ranged from 2.6 to 3.2 dB with control voltage of 2 to 4 V.

The dominant modes of the end cap plate are 46, 91 and 101 Hz. As shown in Fig. 2b, the four rectangular patches (1.3 cm x 5.7 cm) were placed diametrically at 90 degree interval with unequal distance from the center. The edge of Patch 1 is at the center of the end cap, while the edges of Patches 2, 3 and 4 are 6 cm, 7.5 cm and 8 cm from the center, respectively. Again, the various patches were designed to sense and control the various modes. Typical performance of the single patch for broadband noise source is depicted in Fig. 3, which shows a 4.4 dB attenuation at the peak with a control voltage of 7 V. It has been observed that a single patch can attenuate 3.9 to 5.4 dB of a tonal noise source with control voltage of 5 to 21 V. The attenuation of broadband source ranges from 3.0 to 4.7 dB at the peak with V_c of 4 to 12 V. Again, attenuation increases with increasing V_c. Fig. 4 shows the performance of two patches (Patch 1 and Patch 3) on broadband noise source with a control voltage of 10 V. As shown in the controlled case, a 9.0 dB attenuation is achieved at the peak. It should be noted that as the control voltage increases the peak decreases (attenuation increases), while the lower frequency components, i.e., 5, 8 and 22 Hz increase. This is the spillover problem we have experienced when the controller becomes unstable.

Larger damping patches were tested and evaluated to determine the effect of size on vibration control. As shown in Fig. 2c, four larger rectangular patches (2.5 cm x 8.3 cm) were placed diametrically 90 degree apart on the 0.1 mm thick end cap. Results showed a single patch can attenuate 2.7 to 3.2 dB of the first mode, i.e., 37 Hz, with control voltage of 10 V. Up to 6.6 dB attenuation was observed at the second mode at 74 Hz by a single patch with control voltage of

8.5 V. As compared with the smaller rectangular patches with the same control voltage, the larger patches provide higher vibration attenuation.

Results showed the difference in performance of a single patch versus the combination of multiple patches is negligible. For the multiple patch configurations considered, performance of the combination of two or more patches is similar to or sometimes is worse than the single patch. In the unfavorable instances, probably the patches have not been placed optimally to attenuate the particular modes. In this study, the single input and single output (SISO) and single input and multiple outputs (SIMO) approaches have been used. A more robust controller, such as multiple inputs and multiple outputs (MIMO) approach should be used for the highly coupled vibratory system. Furthermore, there is a need for high force and high displacement actuating layer for the control of thick cylindrical shells.

CONCLUDING REMARKS

Vibration of finite cylindrical shell was controlled using active constrained layer damping technique. Three damping patch configurations at various locations were tested and evaluated. Results showed the damping patches bonded on the end cap are more effective than the damping patches bonded to the free end of the cylinder. The size and shape of the damping patch can affect the vibration attenuation. Performance of the combination of two and more patches is similar to the single patch. Overall results showed that active constrained layer damping is viable and has greater vibration suppression than the passive constrained layer damping. To improve the active constrained layer technique, there is a need for high force and high displacement actuating layer, and more robust controllers.

ACKNOWLEDGMENTS

The author wishes to thank Professor A. Baz of the Catholic University of America for many stimulating discussions, and to Dr. T. Chen for his assistance in conducting the experiments.

REFERENCES

[1] A. Baz, "Active Constrained Layer Damping," *DAMPING '93 Conference*, San Francisco, CA, pp. IBB 1-23, February 1993.

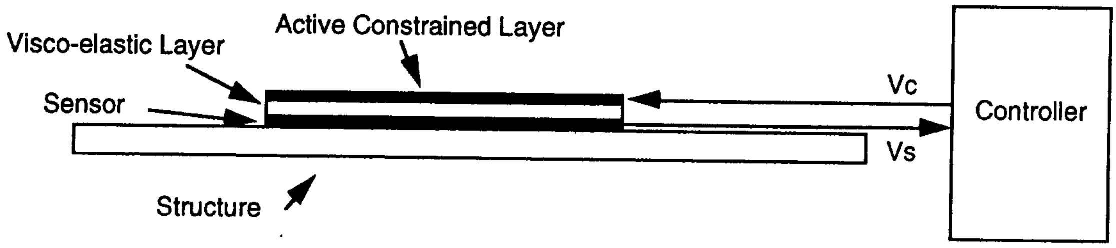

Fig. 1 Schematic of active constrained layer damping technique

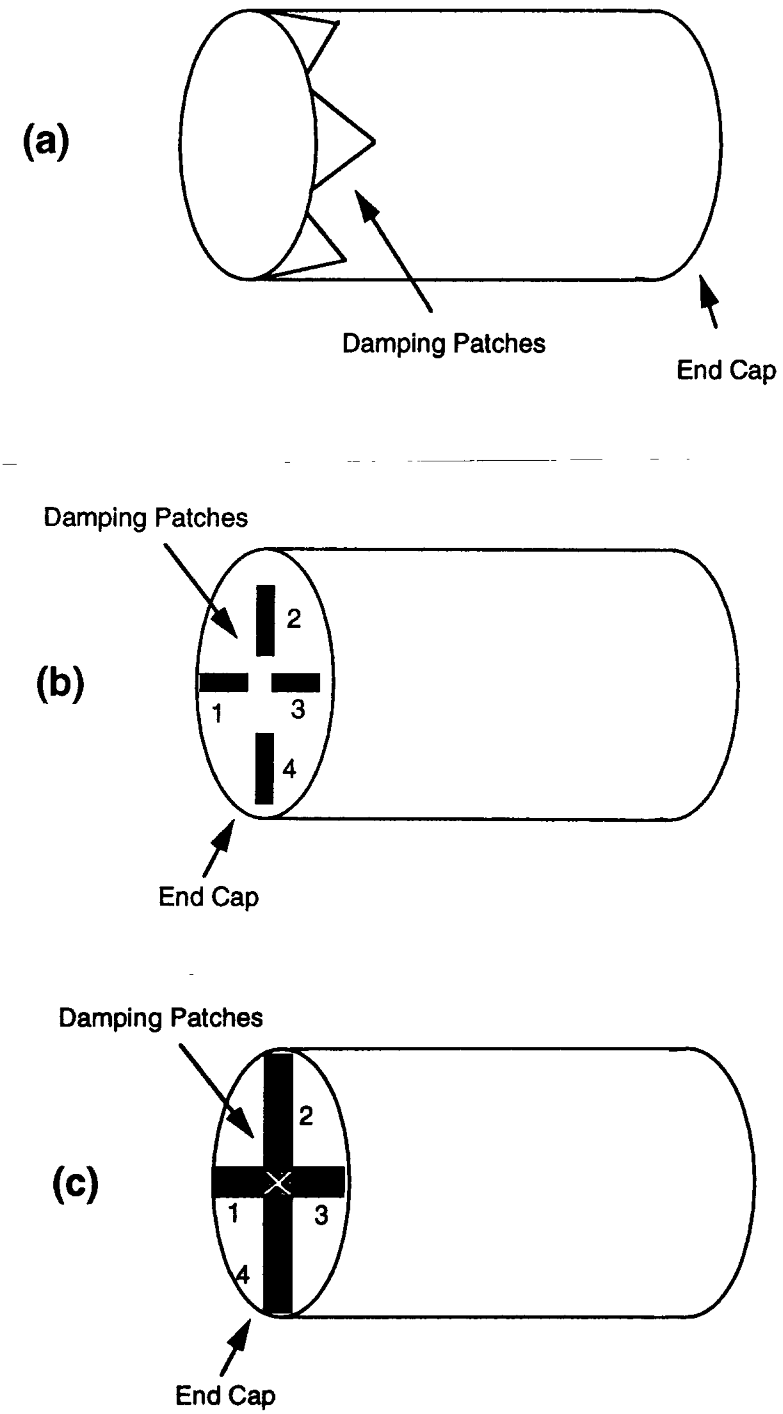

Fig. 2 Schematic of active constrained layer damping configurations: (a) triangular patches on the cylinder wall, and (b) rectangular patches on the end cap

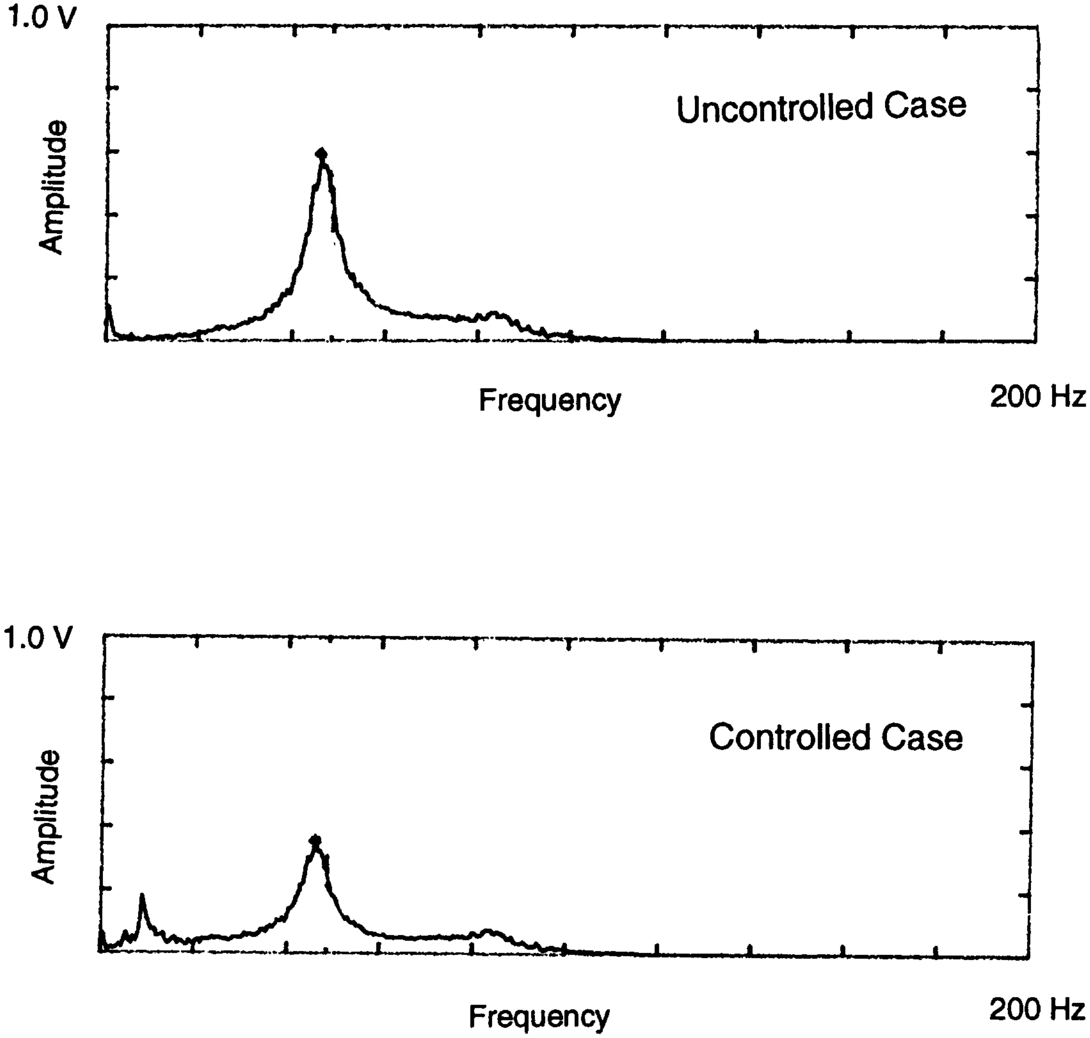

Fig. 3 Performance of single end cap patch on broadband noise

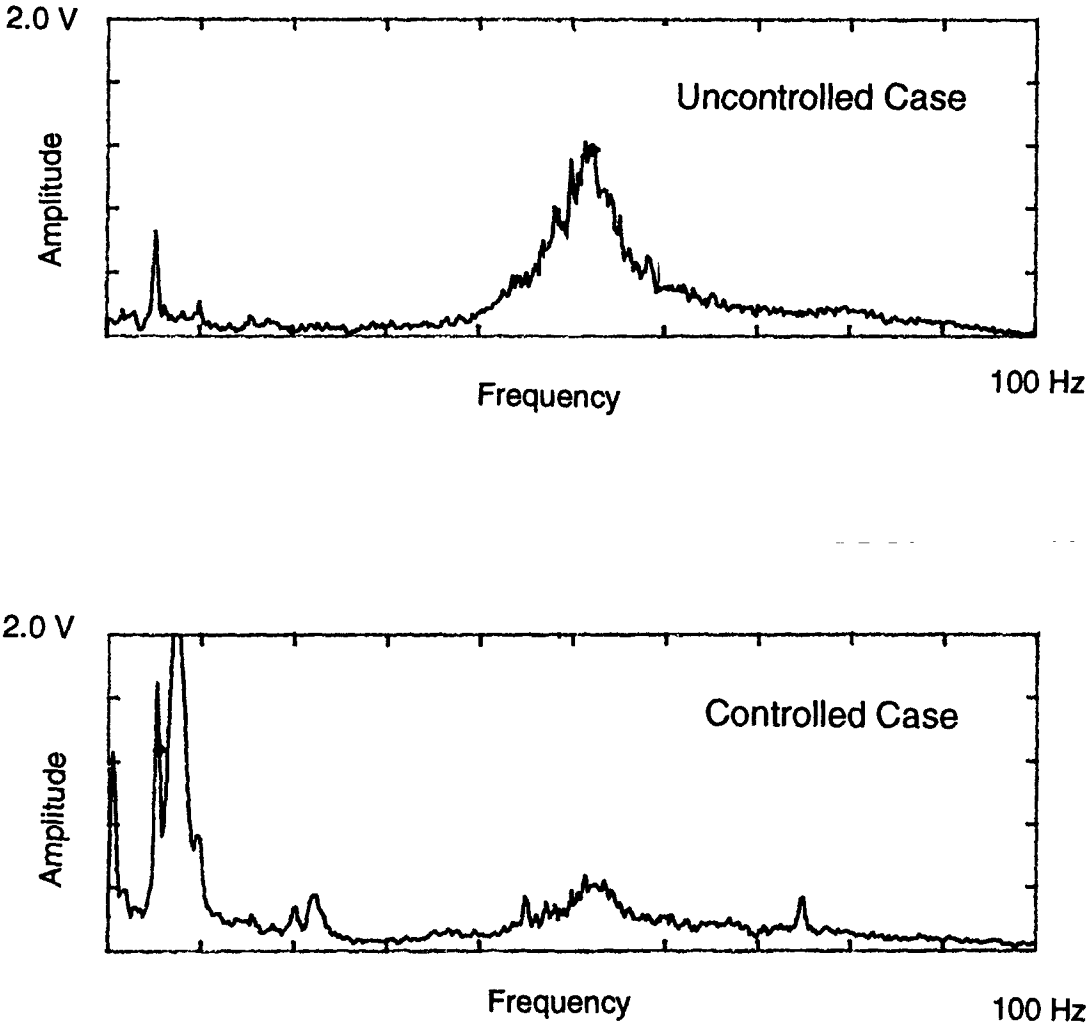

Fig. 4 Performance of multiple end cap patches on broadband noise