

Experiments on the Vibration Attenuation of Honeycomb Sandwich Panels Using MFC Actuators

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ABSTRACT

New all-composite aircraft fuselage designs are being developed with a flexible honeycomb core sandwiched between carbon fiber reinforced composite laminate face sheets. The honeycomb sandwich panels offer potential advantages for significant weight reduction, while maintaining strength and fatigue properties. However, the excessive levels of vibration and noise of honeycomb sandwich panels have been a major cause for concern. Thus, vibration suppression and noise reduction in honeycomb sandwich panels pose major challenges for future aircraft design. In this research, dynamic characteristics of honeycomb sandwich panels were experimentally examined in order to develop efficient and reliable vibration control mechanisms. The experimental measurements of dynamic characteristics of honeycomb sandwich panels were validated using ANSYS finite element model. Macro Fiber Composite (MFC), a newly developed piezoelectric actuator by the NASA LaRC, is typically directional or anisotropic, and more flexible and conformable as compared to a traditional monolithic isotropic piezoceramic actuator. The honeycomb sandwich panel was proposed as a test platform to demonstrate the effectiveness of MFC actuators in vibration suppression of honeycomb sandwich panel. Experimental investigation was implemented to evaluate the effectiveness of vibration control of honeycomb sandwich panel with MFC actuators. Four pieces of MFC actuators are surface-bonded in two effective locations for controlling vibration of lowest four modes. The surface-bonded locations were determined by modal analysis of honeycomb sandwich panel. The results of single mode and multiple modes vibration attenuation with different MFC actuating locations were presented in this study. The study suggested that using the MFC actuators in vibration control of honeycomb sandwich panel had been highly effective.

Keywords : Macro Fiber Composite ; vibration reduction ; honeycomb sandwich panels

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REFERENCES

- [1] 劉孝偉, “複合三明治平板黏彈性分析”, 國立中正大學碩士論文, 指導教授:黃崧任 [2] 楊育彰, “壓電噴射氣流器設計參數效能評估”, 大葉大學碩士論文, 指導教授:羅正忠 [3] www.smart-materials.com [4] Mead, D. J., “The Effect of Certain Damping Treatments on the Responses of dealized Aeroplane Structures Excited by Noise,” Air Force Materials Laboratory Report, AFML-TR-65-284, WPAFE (1965) .
- [5] Agens, G. S. and Napolitano, K., “Active Constrained Layer Viscoelastic Damping,” in 34th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Reston, VA, USA, pp. 3499-3506.
- [6] Baz, A. and Ro, J. “The Concept and Performance of Active Constrained Layer Damping Treatments,” Sound and Vibration Magazine, 18-21, 1994.
- [7] Baz, A. and Ro, J. “Performance Characteristics of Active Constrained Layer Damping,” Shock and Vibration, 2(1), pp. 33-42, 1995.
- [8] Shen, I. Y., “Hybrid Damping Through Intelligent Constrained Layer Treatments,” Journal of Vibration and Acoustics, 118(1), pp.70-77, 1994.
- [9] Yu, X., Zhu, H., Rajamani, R. and Stelson, K.A., “Acoustic Transmission Control Using Active Panels: An Experimental Study of Its Limitations An Possibilities,” Smart Materials and Structures, 16(6), pp. 2006-2014, 2007.
- [10] Sung, C.C. and Chiu, C.Y. “Control of Sound Transmission Through Thin Plate,” Journal of Sound and Vibration, 218 (4) , pp. 608-618, 1998.
- [11] Al-Bassiyouni, M. and Balachandran, B., “Sound Transmission Through a Flexible Panel into an Enclosure:Structural – Acoustics Model,” Journal of Sound and Vibration, 284 (2005) , pp. 467-486, 2004.
- [12] Thomas, D.R., Nelson, P.A., Pinnington, R.J. and Elliott, S.J. “An Analytical Investiga of the Active Control of the Transmission of Sound Through Plates,” Journal of Sound and Vibration, 181 (3) , pp. 515-539, 1995.
- [13] Carneal, JamesP. and Fuller, ChrisR. “An Analytical And Experimental Investigation of Active Structural Acoustic Control of Noise Transmission Through Double Panel Systems,” Journal of Sound and Vibration, 272 , pp. 749-771, 2004.
- [14] Man, P.De, Francois, A. and Preumont, A. “Acoustic Control of Noise Transmission Through Double Wall Structures An Overview of Possible Approaches,” 6th National Congress on Theoretical and Applied Mechanics, Ghent, May 26-27, NCTAM-2003-009, 2003.
- [15] Wanga, J., Lub, T.J., Woodhouseb, J., Langleyb, R.S., and Evansc, J. “Sound transmission Through Lightweight Double-Leaf Partitions: Theoretical Modelling,” Journal of Sound and Vibration, 286 , pp. 817-847, 2005.
- [16] Lin, H.J., Wang, C.N. and Kuo, Y.M., “非等向性FRP 材料聲學 性質及隔音效能之研究,” 中華民國振動與噪音工程學會論文 集, 2006, pp.E-70-E75, 2006 [17] Osman, Haisam “Transmission Loss Testing and Analysis of a Curved Sandwich Composite Panel,” 10th AIAA/CEAS Aeroacoustics Conference, CA 92647, USA, pp. 2004-2821.
- [18] Peters, Portia R., Rajaram, Shankar and Nutt, Steven “Sound Transmission Loss of Damped Honeycomb Sandwich Panels,” INTER-NOISE, HONOLULU, HAWAII, USA, 3-6 DECEMBER 2006.
- [19] Zhu, H., Yu, X., Rajamani, R., and Stelson, K.A., “Active Control of Glass Panels for Reduction of Sound Transmission Through Windows,” Mechatronics, Vol.14, pp. 805 – 819, 2004.
- [20] Kang, Y. K., Hwang, W. and Han, K.S., “Optimum Placement of Piezoelectri Sensor /Actuator for Vibration Control of Laminated Beams,” AIAA Journal, Vol.34 no.9 pp.1921-1926, 1996.
- [21] Kerwin, E.M. and Jr., “Damping of Flexural Waves by a Constrained Viscoelastic Layer,” J.Acoust.Soc.Am, Vol.31, pp.952-962, 1959.
- [22] Wang, H.J. and Chen, L.W., “Vibration and Damping Analysis of a Three-Layered Composite Annular Plate with a Viscoelastic Mid-Layer,” Composite Structures, Vol .58, Issue 4, pp. 563-570, 2002.
- [23] Huang, S.C.and Chen, Y.C., “Parametric Effects on the Vibration of Plates with CLD Treatment,” Journal of the Chinese Society of Mechanical Engineers, 20(2), pp.159-167, 1999.
- [24] Ahmadiam, M. and Jeric, K.M., “On the Appliction of Shunted Piezoceramics for Increasing Acoustic Transmission Loss in Structures,” Journal of Sound and Vibration, 243 (2) , pp. 347-359, 2001.
- [25] Ko, B., and Tongue, B. H., “Acoustic Control Using a Self-Sensin Actuator,” Journal of Sound and Vibration, 187 (1) , pp.145-165, 1995.