Study of Piezoelectric-Actuated Synthetic Jet Flow

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ABSTRACT

Piezoelectric synthetic jet actuators have shown great potential in practical application as active flow control devices due to the advantages of light weight and high efficiency. During the operation, the synthetic jet flow has the cycle-averaged property of zero-net-mass-flux but nonzero momentum flux. The purpose of this study is to probe the compressible turbulent synthetic jet flow characteristics for a dual diaphragm piezoelectric actuator. In the experimental investigation, a flow visualization system was established to obtain the particle streak images with 10- μ m red fluorescent spheres for the piezo-driven synthetic jet flowfield, produced by a dual-diaphragm piezoelectric actuator. In operation, the piezo diaphragms of the actuator were simultaneously driven by a sine waveform. A 5W argon- ion laser with a cylindrical lens was employed to illuminate the flowfield in the cross-sectional plane. The streakline scattered from the fluorescent particles was photographed using a charge-coupled device (CCD) camera. The centerline velocity of the synthetic jet was measured using a hot-wire anemometry system for the code validation. A computational approach also adopted the transient three-dimensional conservation equations of mass and momentum with the moving boundary specified to represent the piezo diaphragm motion. The k-e two-equation turbulent model was used for turbulence closure. The particle streakline images in the cross-sectional plane at the resonant frequency of 648 Hz obviously visualized a fully - developed turbulent jet flow pattern in the far- field area. The close view photograph revealed the timeperiodic formation and advection of discrete vortex pairs. The hot-wire anemometry results showed that the measured centerline velocity of the synthetic jet reached 3.8 m/s at y/d= 50. The numerical simulation indicated that the near- field flow tended to undergo transition to turbulence. In addition, the orifice fluid was entrained into the actuator cavity due to the outward movement of the piezo diaphragms when the vortex pairs were sufficiently distant away from the orifice.

Keywords : Synthetic Jet, Flow Visualization system

Table of Contents

REFERENCES

[1] J. E. Cater and J. Soria, “ The evolution of round zero-net-mass-flux jets, ” J. Fluid Mech. 472, 167 1997.

[2] B. L. Smith and A. Glezer, “ The formation and evolution of synthetic jets, ” Phys. Fluids 10, 2281 1998.

[3] Venkata Pavan K Madhira, “ Interaction of Synthetic Jets with Boundary Layers, ” Fluid Sciences, Department of Mechanical Engineering, UNM, Albuquerque, NM 87131, USA.

[4] Smith, B. L. and Glezer, A. “ Vectoring and Small Scale Motions Effected in Free Shear Flows Using Synthetic Jet Actuators ”, AIAA Paper 97-0213, 1997.

[5] Allen, M. G. and Glezer, A. “ Jet Vectoring Using Zero Mass Flux Control Jets ”, AFOSR Workshop at Wright Patterson AFB, 1995.

[6] Pack, L. G. and Seifert, A. “ Periodic Excitation for Jet Vectoring and Enhanced Spreading ”, AIAA Paper 99-0672, 1999.

[7] Smith, D. R., Kibens, V., Parekh, D. E. and Glezer, A. “ Thrust Vectoring with Hybrid Synthetic Jet Actuator ”, Proc. of the ASME Fluids Engineering Division Summer Meeting, Vancouver, B.C., 1997.

[8] Smith, B., L., Synthetic Jets and their Interaction with Adjacent Jets, PhD Thesis, Georgia Institute of Engineering, 143 pp., June 1999.

[9] Mallinson, S. G., J. A. Reizes, and G. Hong, “ An Experimental and Numerical Study of Synthetic Jet Flow, ” Aeronautical Journal, Vol. 105,

No. 1043, pp. 41 – 49, January 2001.
[10] Rizzetta, D. P., M. R. Visbal, and M. J. Stanek, “ Numerical Investigation of Synthetic Jet Flowfields, ” AIAA Journal, Vol. 37, No. 8, pp. 919 – 927, August 1999.
[11] Lee, C. Y. and Goldstein, D. B. “ Tow Dimensional Synthetic Jet Simulation, ” AIAA Journal, Vol. 40, No. 3, pp. 510 – 516, March 2002.
[12] Mallinson, S. G., C. Y. Kwok, and J. A. Reizes, “ Numerical Simulation of Micro-fabricated Zero Mass-flux Jet Actuators, ” Sensors and Actuators A: Physical, Vol. 105, pp. 229 – 236, 2003.
[13] Wang, Y., “ Microfluidic Technology for Integrated Thermal Management: Micromachined Synthetic Jet, ” Ph. D. thesis, Georgia Inst. Technol., Atlanta, GA, November 2003.
[14] Coe, D. J. , “ Fabrication Technology Approaches to Micromachined Synthetic Jets ” ,Ph.D. Dissertation ,Georgia Institute of Technology,2002.
[15] Amitay, M., Honohan, A., Trautman, M., and Glezer, A., “ Modification of the Aerodynamics Characteristics of Bluff Bodies, ” AIAA Paper 97-2004, 1997.
[16] Roos, F. W., "Synthetic-Jet Microblowing for Forebody Flow-Asymmetry Management", AIAA Paper 98-0212, 1998.
[17] Crook, A., Sadri, A. M., and Wood, N. J., "The Development and Implementation of Synthetic Jets for the Control of Separated Flow", AIAA Paper 99-3176, 1999.
[18] Van Doormaal, J. P., and Raithby, G. D., “ Enhancements of The SIMPLE Method for Predicting Incompressible Fluid Flows, ” Numerical Heat Transfer, Vol. 7, 1984, pp. 147-163.
[19] Pilliod, J. E., and Puckett, E. G.. “ Second Order Volume-of-Fluid Interface Tracking Algorithms. ” Journal Computational Physics, Vol. 188, No. 1, 2003, pp.100-122.
[20] 吳坤城, “ 改良式合成噴射氣流器有限元素模型的建立和實驗量測與驗證 ” , 大葉大學機械工程研究所碩士論文, 2002.
[21] 陳華斌, “ 壓電噴射氣流器的設計與實驗評估 ” , 大葉大學機械工程研究所碩士論文, 2003.