17th AIAA/CEAS Aeroacoustics Conference (32nd AIAA Aeroacoustics Conference)
05 - 08 June 2011, Portland, Oregon

AIAA 2011-2939

Resonance-Enhanced High-Frequency Micro-Actuators with Active Structures

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Research in actuator development over the past few years has been driven towards increasing their amplitude and bandwidth thus enabling users to refine and adapt actuators for a wide array of applications. Recent developments at the Advanced Aero Propulsion Laboratory (AAPL) at Florida State University (FSU) have produced a micro-actuator that is capable of producing pulsed, supersonic microjets by utilizing a number of micro-scale, flow-acoustic resonance phenomena – this is referred to as the Resonance-Enhanced Microjet (REM) actuator. Studies at AAPL have shown that the micro-actuator volume is among the principal parameters in determining the actuator's maximum-amplitude frequency component. Smart materials (specifically piezoelectric ceramic stack actuators) have been implemented into the micro-actuator to actively change its geometry, thus permitting a rapid change in the output frequency of the micro-actuator. The distinct feature of this design is that the smart materials are not used to produce the primary perturbation or flow from the actuator (which has in the past limited the control authority of other designs) but to change its dynamic properties. In this initial implementation of smart structures in the REM actuators, various static and dynamic control inputs to the piezo-stacks illustrate that the actuator frequency can be varied by almost 100 Hz. The very fast response times of the piezoelectric materials are shown to enable rapid tuning of the micro-actuator. Detailed correlations examining the relationship between the piezoelectric actuators' control signal and the micro-actuator flowfield are presented. It is anticipated that future improvements in the design and strategic implementation of smart structures in REM actuators will significantly improve their performance allowing for rapid frequency modulation over a larger dynamic range.

Nomenclature

d	=	source jet nozzle inner diameter
h	=	distance between source jet nozzle and micro-actuator impingement cavity entrance
NPR	=	source jet nozzle pressure ratio ($NPR = P_0/P_{amb}$)
P_0	=	stagnation pressure upstream of the source jet nozzle
P_{amb}	=	ambient atmospheric pressure
V	=	micro-actuator internal volume
ΔV	=	change in the internal volume of the micro-actuator

I. Introduction

FLOW control actuators have received widespread attention in recent years due to their ability to reduce or eliminate adverse effects that arise in a number of different aerodynamic applications. Researchers in actuator development have been attempting to increase actuators' amplitude and bandwidth such that users may be able to adapt actuators for a number of active flow and noise control applications.[1-5] Active flow control has been used to reduce oscillations in the shear layers of supersonic cavity flows,[6] reduce or eliminate flow oscillations and acoustic

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