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Studies on the Resonance-Enhanced Micro-Actuator with Active Structures

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The need for actuators that are adaptable for use in a wide array of applications has been the motivation behind actuator development research over the past few years. At the Advanced Aero Propulsion Laboratory at the Florida State University, a novel, fluidic-based micro-actuator has been developed that produces pulsed, supersonic microjets by utilizing a number of micro-scale, flow/acoustic resonance phenomena. This Resonance-Enhanced Microjet (REM) actuator has been tested for flow and noise control in a few flowfields in an open loop manner only. In order to use this actuator in a closed loop, feedback control system, a modified design that incorporates smart materials is being studied. In the design explored here, a set of piezoelectric ceramic stack actuators (piezo-stacks) are integrated to actively control part of the geometry, thus producing changes in the micro-actuator's resonance frequency. By controlling the voltage applied to the piezo-stacks, the frequency of this actuator can be actively and rapidly $\mathcal{O}$(1 ms) tuned over a very large range: frequency shifts greater than 1 kHz are attainable with the current design. The piezoelectric stacks are also shown to enable closed loop control of the micro-actuator's frequency, a nontrivial task for fluidic-based actuators.

Nomenclature

d	=	source jet nozzle inner diameter
f	=	piezo-stack control signal frequency
h	=	distance between source jet nozzle and micro-actuator impingement cavity entrance
n	=	current time step in the frequency sensor
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
x	=	input to the infinite impulse response (IIR) filter in the frequency sensor
y	=	output of the IIR filter
V	=	micro-actuator internal volume
α	=	filter coefficient in the IIR filter
Δf	=	change in the micro-actuator frequency
ΔV	=	change in the internal volume of the micro-actuator

I. Introduction

IMPROVING the performance of actuators used for active flow and noise control applications has been the focus of many studies over the past few years. Various actuators have shown promise in reducing or eliminating some adverse effects that are present in a number of different aerodynamic applications.[1-6] For the control of high-speed flows, actuators must possess high-bandwidth and high-amplitude to effectively manipulate the high-momentum flowfield. For certain applications, high-speed flowfields have strong adverse effects that can be detrimental to the aerodynamic surfaces of aircraft as well as structures or personnel on the ground in surrounding areas. One such

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