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DEVELOPMENT AND CHARACTERIZATION OF HIGH BANDWIDTH MICRO-ACTUATOR

John T. Solomon
Department of Mechanical Engineering
Florida A & M and Florida State University
Tallahassee, USA
johnts77@gmail.com

Rajan Kumar
Department of Mechanical Engineering
Florida A & M and Florida State University
Tallahassee, USA
drrajank@gmail.com

Farrukh S. Alvi
Department of Mechanical Engineering
Florida A & M and Florida State
University Tallahassee, USA
alvi@eng.fsu.edu

ABSTRACT

This paper describes an experimental study conducted at the Advanced Aero Propulsion Laboratory (AAPL) on the design and development of actuator systems capable of producing high bandwidth, high momentum microjet arrays for active flow control applications. Using a simple geometry of a cavity with arrays of micro nozzles at the bottom end along with a primary source jet, highly unsteady microjets were produced in a frequency range of 6-60 kHz. The unsteady microjets, which are supersonic, have a mean velocity in the range of 300-400 m/sec with an unsteady component between 50-100 m/sec. Such actuators show considerable promise for flow control applications, especially in the supersonic domain. Notable characteristics of this design are its simplicity and the flexibility in controlling the frequency and amplitude suitable for the application of interest. The influence of feedback loop driven shear layer instability and other possible resonant mechanisms on the micro-actuator frequency response are outlined in the present paper. The location of cavity orifice within the Region of Instability (ROI), which is found to be the pressure recovery region of first shock cell of the source jet, plays a very important role in the output frequency and amplitude of the actuator. The length of the actuator cavity is another parameter that strongly influences the frequency of the actuator output. By using high resolution Micro-Schlieren images it was found that the frequency variation with Nozzle Pressure Ratio (NPR) is related to the shock cell properties of primary jet. As a result of this study, we have a better understanding of the geometric and flow parameters governing the unsteady properties of the actuator flow; an understanding that will be used to specifically tailor actuator design for various applications.

INTRODUCTION

Active flow control for a wide array of applications has seen a surge of actuator development activity in recent years due to the potentially substantial gains in performance offered by flow control schemes. For example, control or delay of flow separation over airfoils and lifting bodies can significantly extend the operating envelope of aircraft by improving their aerodynamic performance. The control of aeroacoustically induced flow oscillations in cavity flow is one area where various active (and passive) control methods are being explored (Zhuang et al., 2006). Another ideal candidate for the use of flow control is the flowfield generated by supersonic impinging jets (Alvi et al., 2003, Lou et al., 2006 and Kumar et al., 2008) Such flows are ubiquitous in many applications, such as in STOVL aircraft during hover, and result in a highly unsteady flowfield with very high acoustic levels and dynamic pressure loads in the near-field. These examples demonstrate that flows where control can be applied are wide and varied with more applications are likely to appear as the technology matures.

Efficient control of flows requires the use of effective actuators, which can be adapted for specific applications. Among the most common actuators used are piezoelectric material based actuators, which can be fabricated in various

