

High-Speed Active Flow Control

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The generation of plasmadynamic discharges for near-surface aerodynamic control holds promise for several applications, including rapid and flexible steering control, reduction of noise and structural fatigue from open cavities, and boundary layer

control on advanced, high-speed flight vehicles. Effective manipulation of a flow field using flow-control technologies can lead to a number of significant benefits to aerospace vehicle systems, including enhanced performance, maneuverability, payload, and range, as well as lowered overall cost.

A research team led by APL is investigating the time-dependent fluid dynamic interactions between colocated pulsed jets in order to demonstrate a potentially revolutionary system for high-speed flow control that leverages SparkJet technology (Fig. 1). The plasmadynamic SparkJet actuator generates exhaust streams that can penetrate supersonic as well as subsonic boundary layers.

Operated at high frequencies (~1 kHz), the unsteady actuation can be targeted to influence the inherent

instabilities of supersonic flows requiring small inputs for a large effect. Investigation of a single SparkJet operating at low frequency (1–2 Hz) in quiescent flow is required to understand the operation of the device. Computational fluid dynamics (CFD) has been used to visualize the jet from the orifice and to perform parametric studies of this jet, varying the spark energy and physical geometry of the device (Fig. 2).

To validate and build confidence in the CFD model, the team at JHU Homewood experimentally captured the SparkJet using particle image velocimetry and digital speckle tomography techniques (Fig. 3). In addition, measurements of the unsteady pressure inside the cavity during

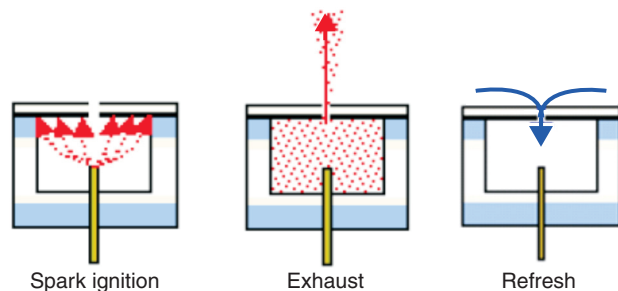


Figure 1. Three-stage actuation cycle.

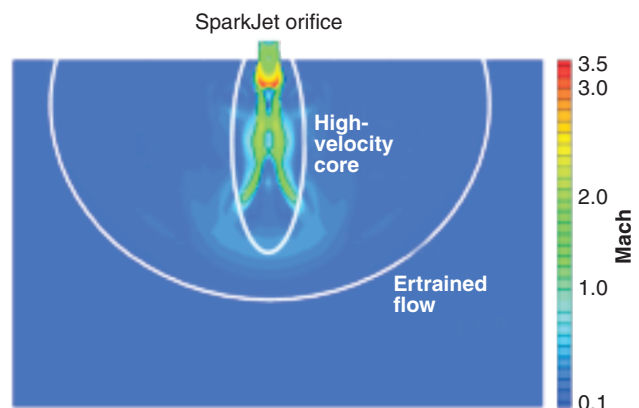


Figure 2. SparkJet firing downward.

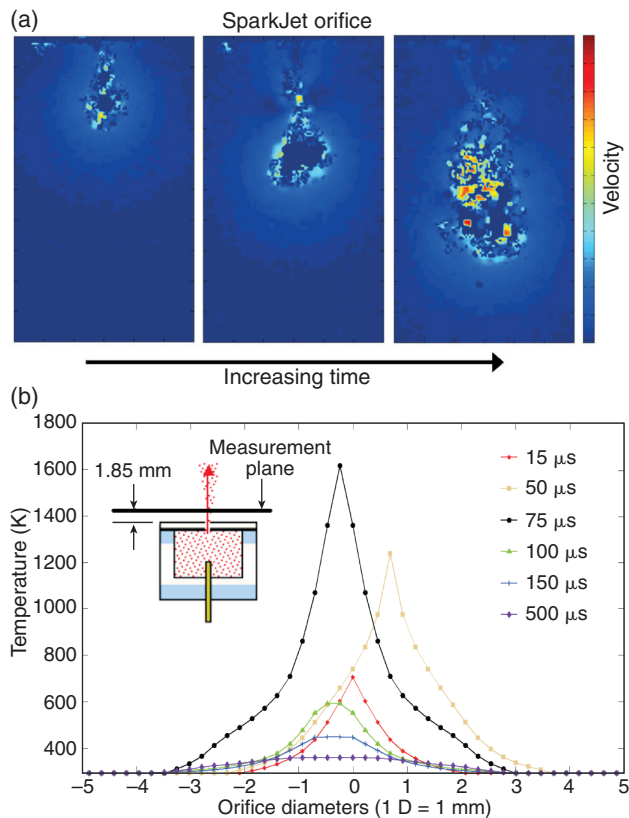


Figure 3. (a) Particle image velocimetry used to visualize the entrained flow in quiescent air. (b) Digital speckle tomography temperature profile of SparkJet plume 1.85 mm above orifice.

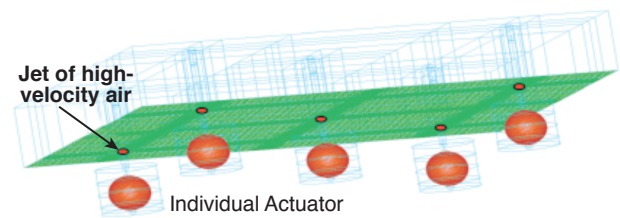


Figure 4. Modeled actuator array.

actuation will be used to complement the development of a lumped parameter model for a single actuator.

Practical application of the actuator technology will require development of an array of individually programmable plasmadynamic actuators; therefore, this lower-order model will be expanded to model an array of actuators (Fig. 4). Validation of the lumped parameter model for an array will occur in a wind tunnel test designed to investigate the capability of the SparkJets in reducing noise from an open cavity in supersonic flow.

Under Air Force Office of Scientific Research sponsorship, both computational and experimental techniques are being used to investigate the fundamental operating modes of a prototype actuator array once the pulsed jet phasing and potential amplification effects are fundamentally understood and a lumped parameter model is developed to optimize an array of individually programmable plasmadynamic actuators for the desired application.

For further information on the work reported here, see the references below or contact sarah.haack@jhuapl.edu.

¹Haack, S., Land, B., Cybyk, B., Ko, H. S., and Katz, J., "Characterization of a High-Speed Flow Control Actuator Using Digital Speckle Tomography and PIV," AIAA-2008-3759, Presented at the 4th Flow Control Conference, Seattle, WA (23–26 Jun 2008).

²Cybyk, B. Z., Grossman, J. K., Wilkerson, J. T., Chen, J., and Katz, J., "Single-Pulse Performance of the SparkJet Flow Control Actuator," AIAA-2005-401, Presented at the 43rd AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV (10–13 Jan 2005).