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Effectiveness of SparkJet for Flight Control

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Abstract

The SparkJet is a device for generating a short time duration micro-jet with high specific impulse. Initial development was performed at the Johns Hopkins University Applied Physics Laboratory by Cybyk *et al*[1]. The basic concept is illustrated in Fig. 1. A DC spark discharge is confined within a small cavity (≈ 1 cm^3) with a converging nozzle. The resultant high pressure gas exits the cavity generating a short duration (≈ 1 ms) impulse. Subsequent to the discharge, gas refills the cavity and the process may be repeated.

Anderson and Knight developed an analytical ideal gas model of the impulse generated by a single SparkJet discharge[2]. The results indicate that the dimensionless impulse $I/\sqrt{\rho_\infty VQ}$ is a function of the dimensionless energy deposition parameter $\varepsilon = Q/p_\infty V$ where ρ_∞ is the ambient density, p_∞ is the ambient static pressure, V is the volume of the SparkJet cavity and Q is the heat added (Fig. 2). The analytical model shows excellent agreement with detailed inviscid CFD results (Fig. 2).

The paper for EUCASS 2013 will focus on analysis of the capability of the SparkJet for flight control of hypersonic air vehicles. Preliminary assessment[3] of an array of SparkJets (Fig. 3) covering 12.5 cm $\times$ 12.5 cm area with a packing fraction of 0.5 indicates a specific impulse $I_{sp} = 10,000$ s.

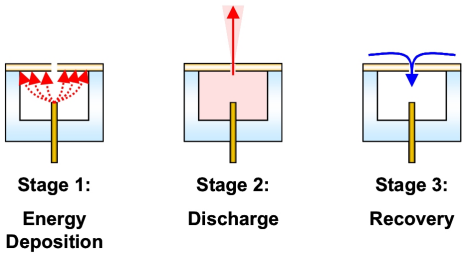

Figure 1: SparkJet[1]

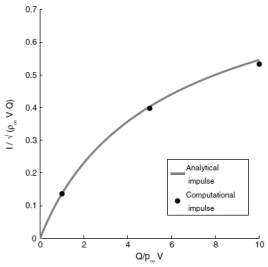

Figure 2: Impulse *vs* energy[2]

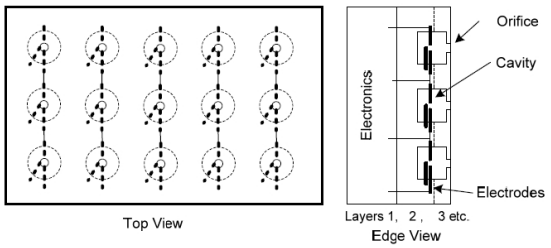

Figure 3: SparkJet Array[4]

References

[1]Grossman, K., Cybyk, B., Rigling, M. and Van Wie, D., "SparkJet Actuators for Flow Control", AIAA Paper No. 2003-0057, American Institute of Aeronautics and Astronautics, 2003.
[2]Anderson, K. and Knight, D., "Plasma Jet for Flight Control", *AIAA Journal*, Vol. 50, No. 9, 2012, pp. 1855–1872.
[3]Anderson, K. and Knight, D., "Feasibility Analysis of SparkJet for Flight Control", CCD Report 2011-7, 26 April 2011, Department of Mechanical and Aerospace Engineering, Rutgers University.
[4]Cybyk, B., Wilkerson, J. and Simon, D., "Enabling High Fidelity Modeling of a High-Speed Flow Control Actuator Array", AIAA Paper No. 2006-8034, American Institute of Aeronautics and Astronautics, 2006.