Diffusion Plate Fuel Injection into Cavity Flame-Holders in Supersonic Crossflow

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Introduction

- Scramjets, an experimental air-breathing propulsion technology for travel at speeds of Mach 5 and greater, are unique in that they perform combustion at supersonic speeds.
- Residence time in the combustor is very short at supersonic speeds, leading to limited fuel-air mixing and concerns related to ignition delay time.
- Cavity flame-holders have been shown to increase residence time and fuel air mixing by providing an area outside of the high-speed crossflow for recirculation zones to form [1].
- Fuel-injection directly into a cavity is being explored to further increase fuel-air mixing.

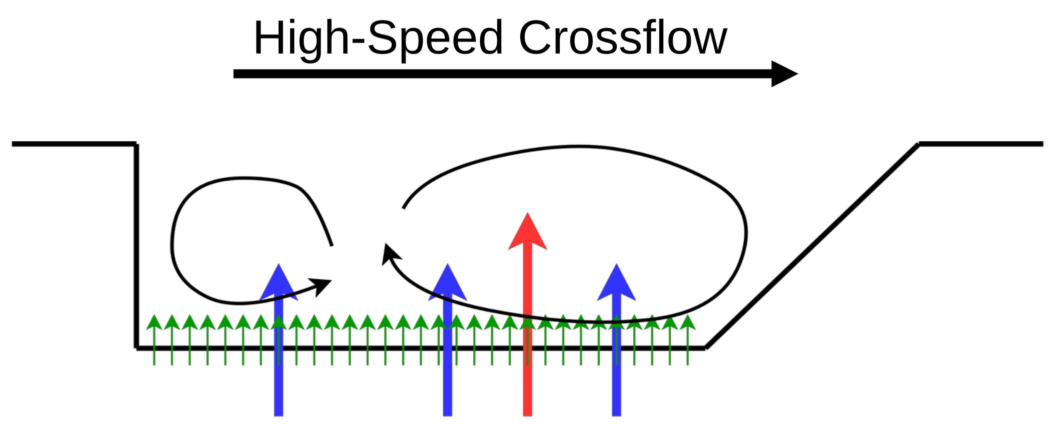

Figure 1. A drawn representation of a cavity and its associated recirculation zones, with (a) single jet (red), (b) multi jet (blue), and (c) diffusion plate (green), vertical fuel injection from the base of the cavity.

Previous Work

- CFD studies have shown increased fuel-air mixing from high momentum ratio multi-jet fuel injection, as compared to high momentum ratio single-jet injection [2].
- This study will experimentally confirm those results and test a low momentum ratio diffusion plate fuel injection along the entire bottom length of a cavity.

Experimental Setup

- This study is using the Lafayette College Expansion Tube impulse facility to generate short test time high-speed flows.
- Ethylene injection into a cavity flame-holder with swappable single-jet, multi-jet, and diffusion injection plates is being performed.
- High-speed visual spectrum intensity imaging is being conducted to visualize flame-size, which correlates with fuel-air mixing.
- High-speed schlieren imaging is being conducted to visualize density gradients to view shock waves and fuel injection.

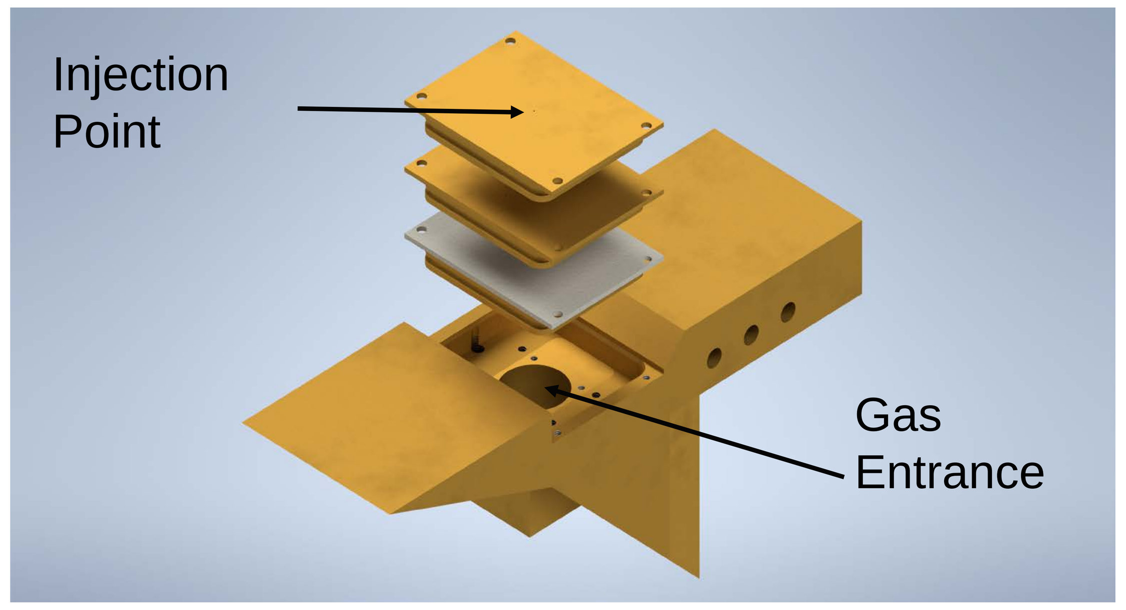

Figure 2. Cavity flame-holder test article with swappable injection plates.

Preliminary Results

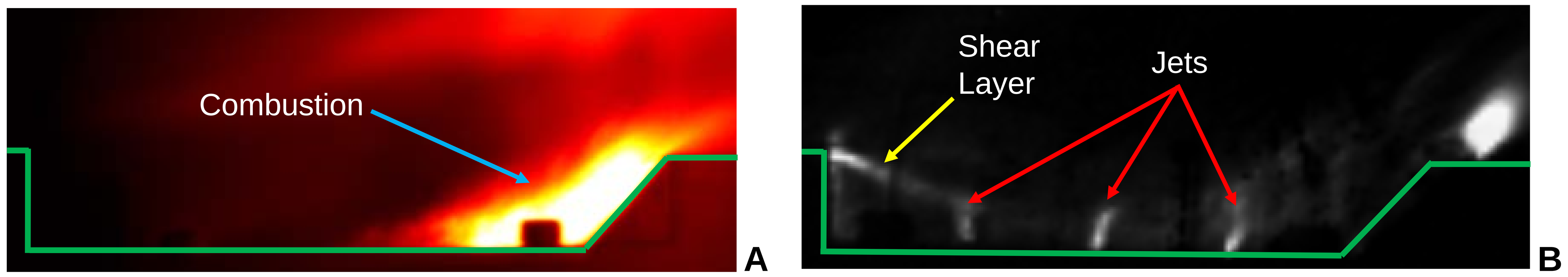

Figure 3. High speed images of the cavity with multi-jet injection at 250 psi and Mach 1.2 crossflow. Taken with (A) visual spectrum intensity and (B) schlieren imaging.

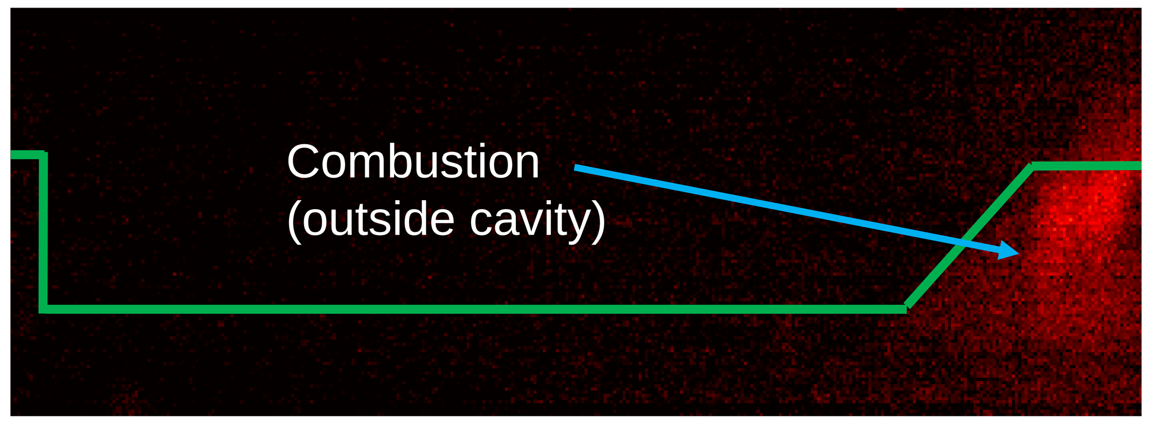

Figure 4. High speed visual spectrum intensity image of the cavity with multi-jet injection at 250 psi in an expanded Mach 4.1 crossflow.

- In Figure 3A, combustion at test conditions is very strong, indicating good fuel-air mixing.
- In Figure 3A, combustion is primarily at the back of the cavity, where the temperature is greatest.
- In Figure 3B, the shear layer can be seen dipping into the cavity, preventing the jet from penetrating into the crossflow.
- In Figure 4, combustion is almost non-existent, indicating that the minimum free-stream temperature was not achieved, due to the expansion of air to achieve a higher Mach number crossflow.

Conclusions and Future Work

- Preliminary results match hypotheses and show good fuel-air mixing in the multi-jet configuration.
- Testing will continue in low Mach number unexpanded flow to maintain the minimum necessary free-stream temperature for combustion.
- Future testing will be conducted with single-jet and diffusion plate injection to compare fuel-air mixing as it relates to flame size.

Acknowledgments

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[2] Amirhossein Edalatpour et al. "Injection of multi hydrogen jets within cavity flameholder at supersonic flow". In: International Journal of Hydrogen Energy 44.26 (May 2019), pp. 13923–13931.

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