Investigation of the Three-Dimensional Behavior of a Plasma Torch Plume in Combination with an Aeroramp and Fuel Injector in a Supersonic Crossflow

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One objective of hypersonic research is to push the limits of space. Ramjet and Scramjet engine development utilizes hypersonic technology to propel aircraft to higher altitudes and greater speeds. Scramjet engines are configured such that combustion occurs at supersonic air velocities through the engine. These engines rely on complex aerodynamic designs rather than complex rotating mechanisms found in jet engines. Such engines will enhance the propulsion of larger crafts at hypersonic speeds. The combustion of fuels inside these engines can be enhanced by a plasma torch in combination with an aeroramp and fuel injector.

This work addresses the specific issue of flame spreading in the x-z plane. The project is an adaptation of Scott Gallimore and Lance Jacobsen's previous work with the Virginia Tech DC plasma torch and aeroramp fuel injection system. It will determine combustion success by identifying combustion intermediates and products of plasma-fuel interaction. The overall goal is to investigate the production of an efficient environment for supersonic combustion by examining the x-z plane, while previous tests looked at the y-z plane.

The experiments will be performed in the cold flow, blowdown supersonic wind tunnel at Virginia Tech in the configuration shown in Figure1. Spectroscopic measurements will be performed while injecting ethylene fuel through the aero-ramp injector and nitrogen feedstocks through the plasma torch igniter. The distribution of fuel-plasma products and the effects of excited hydrocarbon and nitrogen species on the intensity of the fuel-plasma products will be observed, focusing specifically on C_2, CN, CH, and N_2. The results of these new tests will complete the three-dimensional map of combustion species emissions of the plasma torch plume.

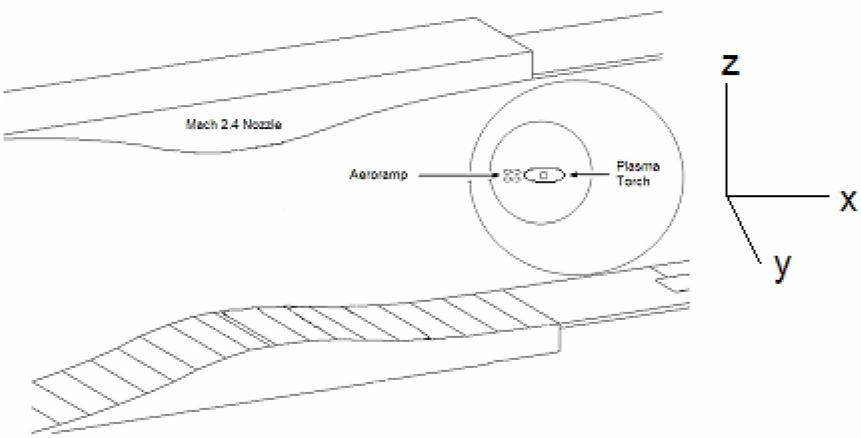

Figure 1. Virginia Tech test section set-up [modified from Gallimore 2001].

In preparation, the two-dimensional experiments of Gallimore, Jacobsen, et al. [2001], were reviewed. From these descriptions new experiments were designed to rotate the test plane about the x-axis so that the x-z plane could be measured by the spectrometer and photographic cameras. Similar equipment, fuel flow rates, and set-up are used. In the Gallimore, Jacobsen, et al. [2001] studies total temperature measurements were taken using a triple-probe temperature rake. These temperature plots will be used to evaluate the similarities between the y-z and x-z planes. It is assumed that the temperatures seen in the y-z experiments are comparable to the temperatures in the x-z plane, so these temperature measurements will not be recollected, rather the y-z temperature plots will be rotated to match the x-z plane. Spectrographic and photographic measurements of the plumes will be taken. After gathering the data, the y-z and x-z measurements will be complied to present the data in a 3-D format and insights into the behavior of the torch and the fuel injector plume will be developed. Results will indicate a similar spectrographic array to the Gallimore, Jacobsen, et al. [2001], experiments. A similar flame spreading angle is also expected.