Section 11.0: Plasma Torch Start/Restart Capabilities

Scramjet applications require a robust, reliable ignition source to maintain strong, stable operation. Engine failure due to flameout is a genuine concern. Extreme turbulence, water vapor ingestion or inlet flow distortion could result in engine flameout requiring multiple restarts. These concerns indicate the need to develop a highly reliable plasma torch that is capable of being relit on a continual basis.

In order to meet the demand for high reliability, the Virginia Tech Plasma Torch had to demonstrate the ability to start and restart in various operating situations. Since variables such as mass flowrate, torch chamber pressure, current setting and high frequency intensity may affect the ability of the torch to operate, variations in each should be investigated. Due to the ease in which the mass flowrate could be controlled with the Sierra 840M units, variation in mass flow was chosen as the starting point for the analysis.

11.1: Testing Setup and Procedure

A standard equipment setup was used for this series of tests with the following modification. Due to the use of a high frequency voltage, the data acquisition system was disconnected from the power supply circuit. The power supplies were each set at approximately 15 amps (A), and the HF starter was set at 5%.

The same testing procedure was used in the analysis of both methane and ethylene. Starting at a certain flowrate, each of the four power supplies was turned on. The HF starter was powered up, and, following a brief pause, the continuous mode switch was activated. The torch was run for one minute with the HF starter operating the entire time. At the end of the minute, the HF starter and power supplies were turned off for five seconds, to simulate a flameout, and then the torch was restarted. The torch was run for a period of 15-20 seconds after restart was established, at which point the HF starter and power supplies were again shut off.

After a short cool-down period, the flowrate was increased by 2 SLPM, and the above procedure was repeated. In all, sixteen tests were completed (8 methane and 8 ethylene) from a range of 16 SLPM to 30 SLPM.

11.2: Results and Discussion

The test results were deemed to be highly promising since the torch was able to re-ignite on the first attempt for all 16 test runs. During low flowrate tests, the torch operated with intermittent fluctuations, but was mostly steady throughout the first 40-50 seconds of the test. At nearly one minute of ethylene operation, fluctuations in the plasma jet became quite severe. However, upon restart, the plasma jet returned to a smooth operating mode similar to that of initial startup. Higher flowrates generated a smooth, stable jet devoid of fluctuations over the entire minute for both gases. The high flowrate cases also had instant reformation of a steady jet on restart.

These observations indicated that flowrates near 30 SLPM were more favorable for start/restart conditions than low flowrates around 16 SLPM. Furthermore, restart of the torch established a steady plasma jet over the full range of flowrates. Also noteworthy, methane operated with less jet fluctuations than ethylene, but the torch re-started using either gas with the same ease.

Apart from these tests, the plasma torch was observed to have an extremely good chance of reignition for cases where the torch blew out for other reasons such as electrode buildup in the anode constrictor. Reignition of the torch cleared any blockages and reestablished a smooth plasma jet. The only circumstances that prevented reignition were when the arc gap became too large, or the electrodes were in physical contact with one another. Under these conditions, reignition is impossible.

11.3: Concluding Remarks

Due to the importance placed upon reliability of the plasma torch, the results of the start/restart tests are quite significant. With the high success rate of the plasma torch on restart, a minimum of redundancies would have to be included in an engine design for reignition. By proving the high reliability of the plasma torch to continually ignite and re-ignite, fewer plasma torches would have to be placed in a scramjet combustor to serve as safety backups.

Although the 15 A and 5% HF setup had perfect restart performance over the 15 SLPM flowrate range, more testing should be done for higher and lower current levels in order to obtain more verification that the plasma torch will "always" restart. Also, starting at various current settings will simulate starting and restarting in off-peak power situations that may occur in actual operation.