Atmospheric Flow Visualization in Hall Effect Thruster Anodes using Premixed Flames

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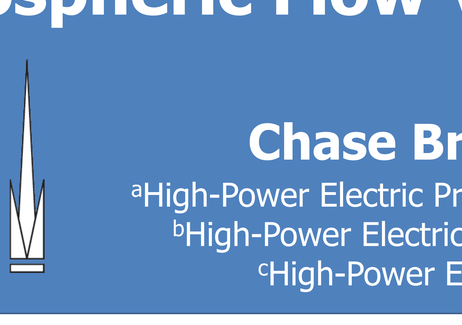
Problem Statement

Characterizing the flow of neutral propellant gas from a Hall Effect Thruster anode is important in projecting **thruster performance, lifetime and operational stability**. The uniformity of the flow at the exit plane plays a large role in determining these characteristics. Experimental methods to model the flow at the anode exit plane have been created, but are complicated, lack spatial resolution, and may perturb the flow. To solve these problems, **flame tests are designed and implemented on the anodes to determine the flow characteristics**.

Figure 1: Cross section of a typical Hall Thruster

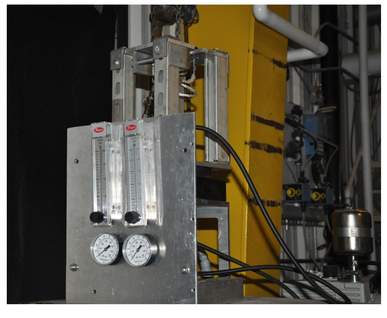


Procedure

A flame is created at the exit plane of the anode using a premixed mixture of air and propane.

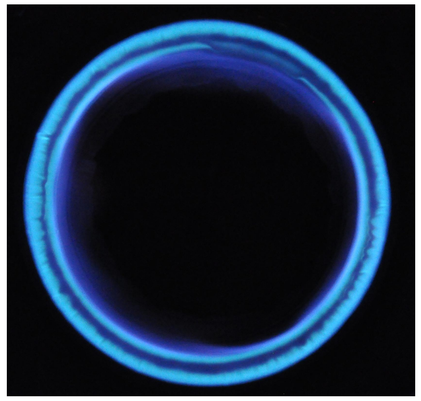
$$C_3H_8 + 3.76N_2 + 5O_2 \longrightarrow 3CO_2 + 4H_2O + 3.76N_2$$

Figure 2: Experimental setup for the uniformity testing of the anode. The mass flow controller, pressure gauges, and anode stand can be seen.



Results: Flame Analysis

Figure 3: Pre-mixed flame test of an Aerojet anode. Notice the defect near the 80 degree mark. The flow is fuel rich.



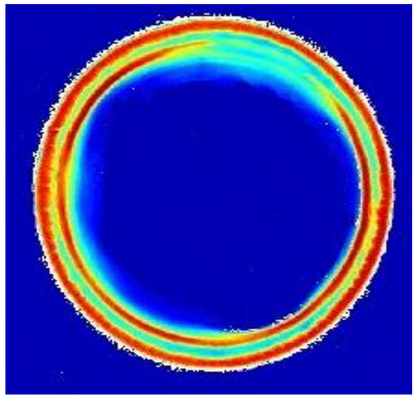
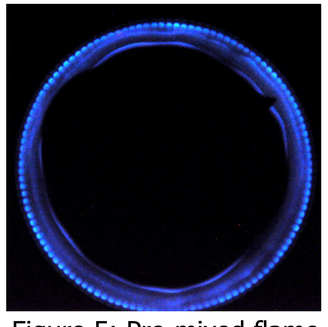


Figure 4: Matlab representation of the same anode using the surf() function. The defect is more apparent here. It appears to be uniform everywhere else.



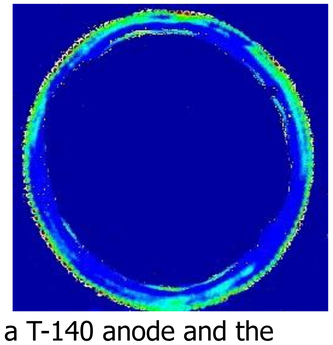


Figure 5: Pre-mixed flame of a T-140 anode and the respective Matlab representation. It is important to look at the exit plane flow to check for uniformity; in this case it is the flamelets around the edge.

Discussion

The method used to check for uniformity is **simple, cheap, and expeditious**. This solves the initial goal laid out in the problem statement. Luminosity is strongest in regions of highest mass flux, and thus the method gives a detailed measurement of the flow uniformity. The results show that non-uniformities are fairly easy to spot using a simple visual inspection of the intensity of the flame on the exit plane. It is important to note that the flow on the exit plane is being measured because that region is the most stable and is least affected by atmospheric conditions. This region also has the greatest effect on the uniformity. Flow conditions (pressure, flow rate, and fuel-air ratio) that show this exit plane flow are required.

Improvements

This experiment has been done for two different anodes. It needs to be repeated for a variety of Hall Effect Thruster anodes. Also, a quantitative value needs to be created to measure uniformity.

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