Section 8.0: Arc Gap/Voltage Gradient Characteristics

Knowledge of the voltage gradient as a function of plasma torch arc gap is useful information when planning for future plasma torch applications. One prime consideration is the effect that changing the arc gap and feedstock gas has on the voltage requirement. Different arc gaps may provide different stable regimes in which torch performance is improved. Larger arc gaps will obviously increase the required voltage, but the limits on arc gap and how arc stability is affected is not as apparent.

Tests were conducted with methane and ethylene to determine the voltage gradient as a function of arc gap. With a limited voltage supply, upper limits of arc gap were found, past which the torch would not ignite. This upper limit was larger for methane than for ethylene.

8.1: Test Procedure

In order to minimize the number of independent variables, only the arc gap was changed. Each test was run at 30 SLPM (about 170-210 kPa) on either methane or ethylene and at constant DC. To start the tests, the plasma torch was set to its normal 0.178mm arc gap and run at approximately 25 amps. The plasma torch was started on high frequency current and then allowed to run on DC only. Once DC operation was initiated, the data acquisition system was turned on. The plasma torch was run for 15 seconds while the DAQ system averaged the voltage. The torch was then shut off and allowed to cool down. The arc gap was readjusted to some higher value, and the test was repeated. This procedure was repeated until the arc gap was too large to allow the plasma torch to operate on DC alone. A first-order least-squares curve-fit was then applied to the data to produce a smooth function of arc gap versus voltage. A first-order curve fit was used because it was found that under a pressure of about 800 kPa, voltage gradient versus arc gap for most gases is linear (Cobine, 1941).
8.2: Results and Discussion

The curve fits for the arc gap tests are shown in Fig. 8.1. It is apparent that ethylene has a much higher voltage gradient ($\approx 180 \text{ V/mm}$) than methane ($\approx 35 \text{ V/mm}$). This is most likely due to ethylene having a more complex chemical structure than methane. Although propylene was not included in this series of tests, it produced an average voltage of about 75 volts when run at the same amount of current and the standard arc gap of 0.178mm. When compared to the voltage gradient data in Fig. 8.1, it is clear that propylene requires more voltage than either ethylene or methane at the standard arc gap. This supports the conclusion discussed earlier in Section 7 that more complex hydrocarbons require more voltage to operate at a given arc gap and have larger voltage gradients. At arc gaps larger than 0.35mm, ethylene required too much voltage from the power supplies to run on DC only. Methane reached this limit at about 0.52mm. Methane has a much wider range of operation and is more tolerant of arc gap settings than ethylene due to its smaller voltage requirement.

Figure 8.1: Voltage vs. Arc Gap (Methane and Ethylene)
8.3: Recommendations and Final Remarks

The arc gap versus voltage tests clearly demonstrated that ethylene has a much higher voltage gradient than methane. This reduces the flexibility (range of arc gaps and voltage) with which the plasma torch can operate when running with ethylene. Higher voltage also increases the electrode erosion rate, because the arc has a larger amount of potential energy. This in turn reduces the operating life of the plasma torch. It would seem that high-voltage arcs have greater potential to dislodge pieces of electrode because of the larger thermal gradients they produce in the anode. As an example, argon arcs require very little voltage when compared to methane or ethylene. Consequently, the electrode erosion rate for argon is also much lower. For smooth hydrocarbon feedstock operation with minimal electrode erosion, methane is recommended because of its low voltage requirement and arc gap flexibility.