Current Distribution in a Quasisteady MPD Arcjet with Various Anode Geometries

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Abstract

THE current distribution in an MPD arcjet was measured under quasisteady operating conditions. Measurement of the thrust performance and spectroscopic observation of the electrode erosion were also made. With a conventional straight geometry anode, current concentration at the cathode base and tip, and severe electrode erosion at high magnetic Reynolds numbers were found, which is consistent with our previous theoretical prediction. With a modified diverging-type anode, the current distribution was found to be the most uniform of the three geometries tested and the thrust efficiency was highest under the erosion-free operating conditions. Another type of converging-diverging anode contour, in contrast to the analytical results, showed rather severe current concentration and electrode erosion.

Contents

It has been generally granted that the MPD thruster should be operated at a large discharge current and a low mass flow rate to obtain high specific impulse and thrust efficiency. In such operating conditions, it has been experimentally found that severe electrode erosion is likely to occur at the cathode base and tip.[1,2] It was supposed that this erosion was caused by the local concentration of the discharge current. Severe electrode erosion is detrimental to a long-duration mission and the current concentration in the plasma stream leads to intense Joule heating that may partially contribute to the electrothermal acceleration in the MPD thruster but certainly results in an energy loss.

The KOMABA-I arcjet[3] with the conventional straight geometry (S) anode and with modified anodes of converging-diverging (CD) and diverging (D) geometries (see Fig. 1) was operated in 1 ms quasisteady conditons with argon gas propellant. The ambient pressure was about 10^{-5} Torr. The current distribution on the cathode surface was measured with split cathodes at different splitting positions.[4] Copper anodes and a tungsten cathode were used to measure the thrust, discharge voltage, and spectral intensities of the plume, while the tantalum split cathodes were used to measure the current distribution.

The current distribution along the center axis is shown in Figs. 2 and 3 for the S-type anode at mass flow rates of 0.2 and 0.05 g/s, respectively. The partial current collected by the surface between the cathode tip and the insulating splitter is expressed as a fraction of the total current and is plotted against the location. The gradients of the lines connecting the experimental points represent the mean values of the current density in the region bounded by the splitting positions. The location and configuration of electrodes are also illustrated in the figures in precise proportion. Slash marks attached to the points in the figures indicate the cases in which the intensity of WI (5006 A) exceeded the intensity of ArII (5062 A). Although the spectral intensity is not precisely proportional to the population of the species, the intensity of WI rapidly grew as the current increased, so that the marked points are con-

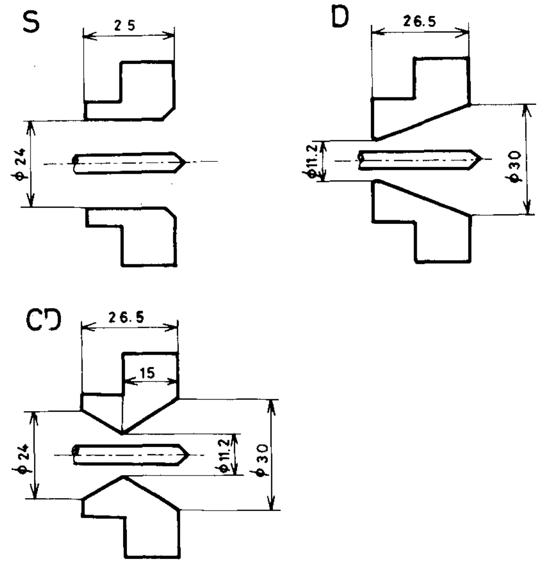

Fig. 1 Anode geometries: straight (S), diverging (D), and converging-diverging (CD).

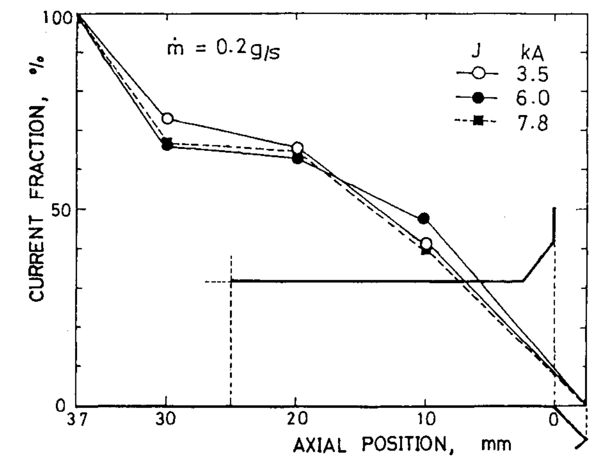

Fig. 2 Fractional current of Ar at 0.2 g/s, straight (S) anode geometry (the fractional current passing through the electrode section plotted against the axial position, which is measured from the downstream edge of the cathode; the electrode geometry is also illustrated).

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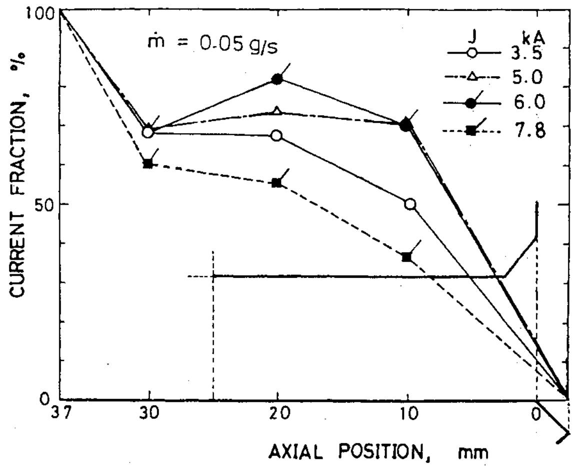

Fig. 3 Fractional current of Ar at 0.05 g/s, straight (S) anode geometry (see Fig. 2 for other specifications).

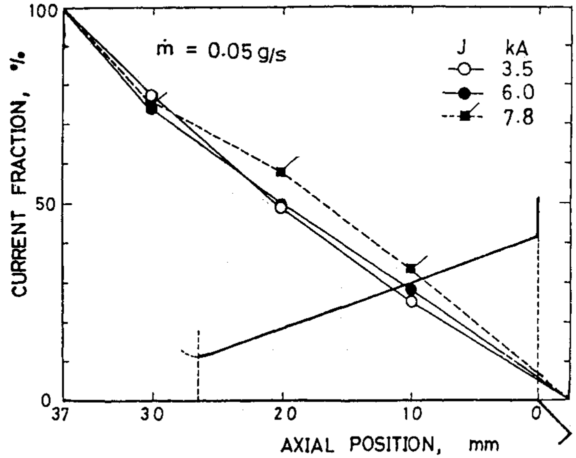

Fig. 4 Fractional current of Ar at 0.05 g/s, diverging (D) anode geometry (see Fig. 2 for other specifications).

sidered to exceed the onset of electrode erosion. With both the large and small mass flow rates shown in Figs. 2 and 3, respectively, the current concentrations at the cathode base were found to be of the same magnitude, while concentration at the tip was found only in the case of a small mass flow rate. The concentration at the tip grew as the current was increased to the limit of the electrode erosion. From these results it was confirmed that the discharge current concentrates at the cathode base and tip as the magnetic Reynolds number increases; that is, as the discharge current increases and the mass flow rate decreases. This is consistent with our previous theoretical prediction.[5] It is concluded that the current concentration is one of the causes of electrode erosion because the erosion started exactly when and where an intense current concentration occurred on the cathode surface. The direction of the current was found to be reversed in the intermediate region of the cathode surface before the erosion started as shown in Fig. 3, but no firm conclusions were developed because of variances in the data.

The current distribution of the D-type anode at a mass flow rate of 0.05 g/s is shown in Fig. 4. In contrast to the S-type, the current distribution was uniform under all of the conditions tested. The CD-type had a more uniform distribution than the D-type at large mass flow rates but the severest concentration at the cathode base and tip was found at small mass flow rates.[4] The electrode erosion of the D-type anode started at the highest magnetic Reynolds number of the three configurations tested. At a mass flow rate of 0.05 g/s, the electrode erosion started when the discharge current reached 5.7, 7.0, and 5.1 kA for the S, D, and CD anodes, respectively. The D anode had the lowest thrust efficiency at low specific impulse, but it had the best resistance against the electrode erosion; thus, it showed the highest thrust efficiency at high specific impulse within the erosion-free conditions.

References

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