Performance Improvement of Vacuum Arc Thrusters

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Abstract

Vacuum arc thrusters (VATs) hold great promise as an attractive pulsed plasma micro-propulsion technology for satellites. To reach their full potential as practical devices, substantial efforts must be made to explore and better understand the intricacies of VAT design and operation. This body of work contributes to this effort by studying a number of new thruster designs, operational modes and cathode fuels that may lead to performance improvement of the VAT. These include (1) the use of millisecond-long arc pulses lengths as a new form of thruster operation, (2) the use of conical cathode shapes, (3) the novel use of carbon and graphite-based materials as cathode materials, and (4) novel heat management using the discrete anode switching technique. Detailed and extensive experimental measurements of thrust, cathode erosion rate, ion current and plasma jet ICDD profiles were undertaken in order to characterise the behaviour and performance of VAT prototypes. Testing was accomplished with the development of a μN-level direct thrust measurement stand, a Faraday Cup probe, a two-axis thruster rotation system, an ion collector and various data collection and processing systems.

In a number of cases, new thruster designs and operations were found to (1) enhance ion production rates, (2) reduce the cathode erosion rate by improving cathode spot motion, and (3) tailor the plasma jet shape towards favourable performance. As a result, several VAT prototypes demonstrated significant increases in thrust production and specific impulse values of up to 100% (~400 μN/A) and 250% (~1000 s) respectively over typical baseline VAT designs (~200 μN/A, 400 s). Several previously unexplored relationships and interactions between VAT performance and thruster parameters such as arc current, arc pulse length, cathode surface geometry, cathode microstructure and thermal properties, plasma jet shape, and cathode spot dynamics were recognised and characterised. The role of the arc pulse length, spot motion and erosion coverage were highlighted as key elements which profoundly impacted on VAT design and performance. This work opens up new areas of VAT design, whilst posing new questions about the fascinating nature and utility of vacuum arc spots for efficient and effective plasma jet production.