§7. A Basic Experiment on an Ion Source for High Power Electromagnetic Plasma Accelerator

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Electromagnetic plasma acceleration has potential to produce very intensive beam of the power density as large as $10^3 \sim 10^4$ times to the usual electrostatic neutral beam sources because the work being done in quasi-neutral state. Nevertheless, no such demonstration has ever appeared. One reason for that may be sought in the fact that at the initial state of the plasma just after ionization of the inlet gas the flow must always be in subsonic state. We learned that the electromagnetic force rather chokes the flow in the subsonic state and the plasma is accelerated only in super sonic state [1,2]. Therefore, efforts have been paid to develop the source ejecting the super sonic plasma flow. Because the entropy acceleration is the most basic way to achieve the super sonic state, we refer an old paper [3] for a space engine for the first step. The engine injects entropy using the wall constricted arc through a thin straight tube. Our trials on the similar principle, however, did not give very successful results. The reason of our failures is ascribed to high thermal conductivity of the plasma, since temperature gradient along the flow plays essential role for acceleration of any compressible fluids in a straight channel. If temperature is constant along a channel as a wall constricted arc, no density gradient is produced, and hence we may say that no acceleration takes place by the conservation law $nv = \text{const}$.

This conclusion lead us to reconsider the nozzle structure. We examined the Laval nozzle under the constant temperature model, and found that the velocity diagram takes the same form to an usual adiabatic gas except the fact that the thermal speed becomes singular instead of the sound speed.

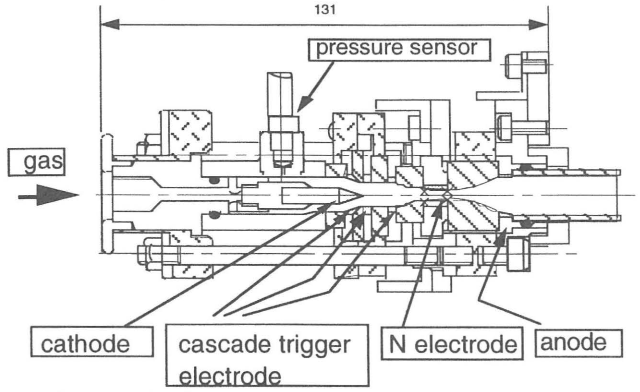

Fig.1 Arcjet ion source with Laval nozzle

We modified the arcjet source to equip the Laval nozzle and the one shown in Fig.1 with the nozzle diameter of 2.5 mm was fabricated. Because both plasma resistance and thermal conductivity scale logarithmically with plasma density, the source is designed to operate around 100 kPa or more for efficient plasma production. The source equips cascade trigger electrodes for easier break down of D_2 gas at an atmospheric pressure or higher. The source mounts "N electrode" to induce large arc current for enabling plasma acceleration in the diverging nozzle. The cathode and the N electrode are connected to electrolytic capacitor source with 825 μF each operated at 1800 V, and the both arc currents are terminated on the anode.

. A typical discharge current and voltage wave forms are shown Fig. 2. It is seen that at quasi-steady phase the arc current is ~2.8 kA and the cathode voltage ~280 V. We confirmed that the discharge are reproducible and the system is quite robust since no damage appears even under huge input of ~800 kW for more than 150 shots.

The evidence that the power input effectively heats up the plasma is shown by pressure probe signal in Fig. 3. We read that the breakdown occurs at ~110 kPa and instantaneously rise to ~260 kPa.

Encouraged by the initial data shown above, we are now preparing more detailed diagnostics for the plasma properties ejected out.

References :
[1] Hirano,K., Journal of Plasma and Fusion Research 69 (1993) 684
[2] Hirano,K., Journal of Plasma and Fusion Research 69 (1993) 806
[3] John,R.R., Bennet,R.R., Conners,J.F., AIAA Journal 1 (1963) 2571

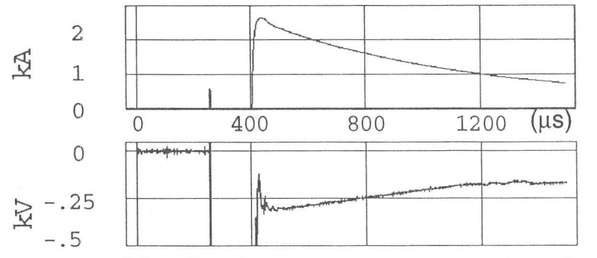

Fig. 2 Anode current (above) and cathode voltage (below)

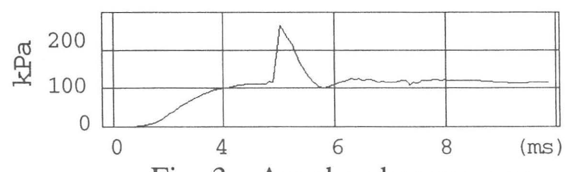

Fig. 3 Arc chamber pressure