§18. Gas Supply Nozzle to a Wall Constricted Arc; Plasma Source Studies for an Intensive Electro-Magnetic Plasma Accelerator

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The power density of the ideal electromagnetic (EM) plasma accelerator can be as high as ~10^4 times to that of the usual NBI source, since the EM force is free from the space charge problem. Tremendous efforts had been paid in many places for such a high power EM system during the two decades starting from 1960. In spite of such efforts, no successful result has ever reported. The key issue for the failures was ascribed to the improper plasma source[1,2]. The source must be the one that ejects out the plasma of the velocity greater than the thermal's, since the EM force works opposite direction to the sub thermal flow. As an example of such seemingly paradoxical effect, the solar wind acceleration may be cited; the gravitational force of the sun works to push out the sub thermal flow into the deep space[3]. It can be said, therefore, that the development becomes essential of a heat engine that boosts up the injected cold gas to the plasma flow of a super thermal velocity. The purpose of the present report is to point out the importance of the gas supply nozzle for the heat engine above.

Primitive theoretical studies[4,5] of the heat engine tell that the physics of plasma acceleration through the arc jet is quite similar to that of the solar wind. The major aspect of the solar wind physics may be sought in the role of viscosity, since the phenomena beyond Parker[3] of the below can be interpreted.

1) Solar wind more energetic than Parker prevails.
2) Lower density solar wind is often more energetic than the denser one.
3) At the far distance from the sun, the solar wind velocity takes the order of the thermal velocity of the electrons involved.

A model arcjet system in Fig. 1 is constructed along with the primitive theories[4,5]. As is seen, the system is composed of the two major parts: the gas injection part and the three-staged plasma heating part of a wall constricted arc. The theory tells that the acceleration is quite sensitive to the temperature profile along the channel. Hence, the staging concept is adopted so as the temperature distribution along the channel may be controlled. It is anticipated that, if the arc current of each section is tailored, then the temperature distribution must also be so.

The working gas is injected into the system from the LHS end by using the fast acting gas valve with the opening time of ~120 μs. The injected gas is fed to the arc channel via the Laval nozzle so as the rapid pressure increase due to arc ignition does not perturb the region upstream of the nozzle. The concept must work since no perturbation is able to propagate against the sonic flow through the throat. If that were the case, the expansion velocity c_{ex} of the gas toward up stream due to arc ignition may be quenched in a time τ_t of the order l_n / c_{ex}, where l_n is the distance between the throat and the arc.

The first trial of the nozzle design based on the concept above was not always successful. The reason may be in the design that ignores the wall friction of the flow. Detailed numerical study must be done.

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. E. N. Parker, in *Interplanetary* dynamic processes (Interscience, New York, 1963) p. 51
4. Hirano, K., Phys. Plasmas 8 1734 (2001)
5. Hirano, K., J. Plasma Fusion Res. SERIES, Vol. 4 (2001), p. 285

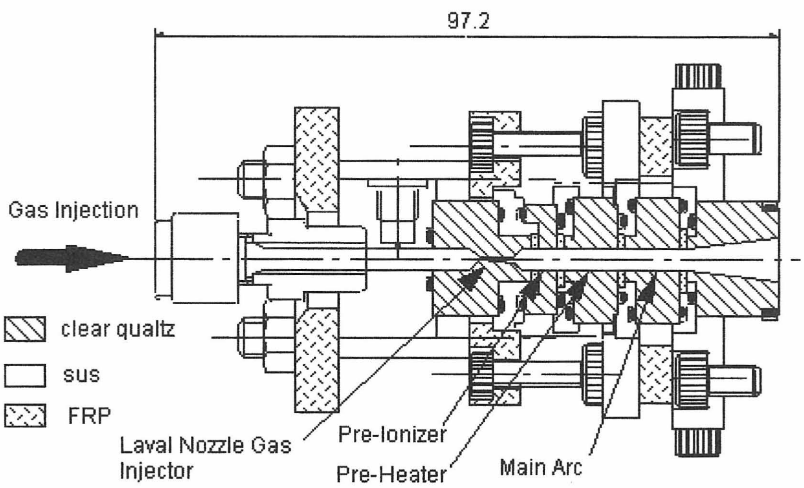

Fig.1: A schematic drawing of the 3-staged plasma heating arcjet system to be tested. The gas ejected out from the fast acting gas valve is guided to the Laval nozzle, by which the sudden pressure increase due to arc ignition is quenched. The system has the three heating sections for the purpose of controlling the temperature gradient along the flow.