§10. Entropy Acceleration of the Plasma by a Small but Intensive Arcjet

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The need of a powerful and energetic but an inexpensive beam source for a commercial fusion reactor has prompted the present work. It was suggested[1, 2] that such a system must be the one using the electromagnetic (EM) force, because the beam current is not limited by the law of Langmuir-Child. Challenge had been done to the EM machine in many places during the two decades starting from the 1960. However, no successful design has ever appeared except the type that runs by the rapid pinching action. This indicates that some design problems must be involved in the steady or the quasi-steady mode machine. The argument has been developed in ref.1, and the fact is implied to be the source that none of them is equipped with a pre-accelerator to inject the plasma at a super thermal velocity into the system; note that the EM force chokes the flow at a sub-thermal velocity.

The analysis of the flow indicates that it must be accelerated by the subsequent two processes, or to say the entropy acceleration must be preceded to the EM mode. Therefore, the development of the entropy accelerator was taken up in the first place.

We employed an arcjet engine for the entropy accelerator, because it has simple structure and is quite tough to high power input. Actually, it was confirmed that there appears no remarkable damage even for 800 kW input into a clear quartz channel of ϕ2.5 mm and length 7 mm during the time of 600 μs.

Several scraps and built were forced to be repeated for an energetic arcjet system. Recently, a clue was found in the design in which the viscosity effect is reflected. More detail theory was then made on the acceleration process by fully taking in the viscosity effects, and the several of its inferences are listed in the below.

1) The dynamic viscosity of the plasma is ~10^4 times greater than that of an ordinary gas, thereby no Laval nozzle is necessary for the flow to exceed the thermal velocity.
2) If the plasma velocity on the cathode surface of the arcjet is set close to the thermal velocity, then the flow is rapidly accelerated to an energetic plasma beam by the action of the pressure and the viscous forces.
3) High thermal conductivity of the plasma also plays good role in smoothly supplying the heat energy to the flow.
4) The entropy acceleration of the plasma may boost up the flow up to the electron thermal velocity, and hence quite an energetic beam may be produced by a well-designed simple arcjet system.

We have constructed a new system in Fig.1 by taking up the physics written above. The key issue for successful plasma acceleration is in precise control of the gas injection velocity so as the one on the cathode surface to be nearly equal to the thermal velocity. For this purpose, the Fano nozzle is equipped to avoid the effect by rapid pressure rise on arc ignition. The Faraday accelerator in the down stream may also be a velocity meter of the plasma flow.

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

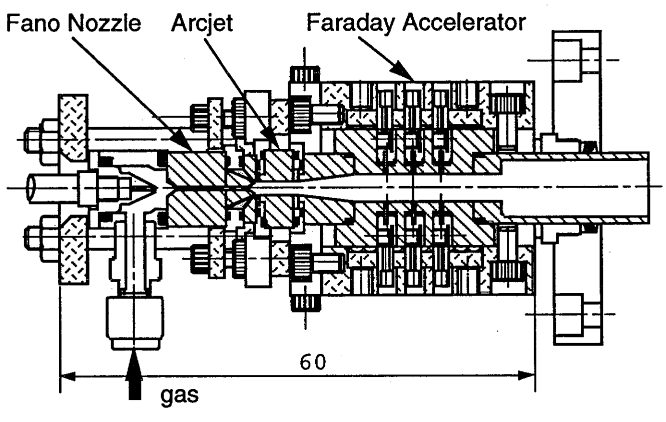

Fig. 1: The newly constructed 3-staged Faraday accelerator of the type having the built-in arcjet plasma source.