§8. Preliminary Inspection on the Particle Supply System Using an Intensive Arcjet Source

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Studies to establish some tractable technic for supplying particles to plasmas offer fruitful advance in various fields of plasma applications including that of the fusion research. We know that in fusion experiments the two methods have mainly been applied: gas puffing to the outer edge of the plasma and ice pellet injection. In addition to the two, there appeared recently a compact toroid injection by forming it externally using a coaxial gun, and particle supply deep into the confined plasma was tested.

Here, we are interested to use an arcjet that ejects simple plasma jet continuously instead of a impulsive compact toroid bearing the complex structure inside. The classical theories therefore about plasma motion across the magnetic field may well be applied to our system. We remind that, in a typical case of the energetic gun, the plasma does not go across the solenoidal field greater than 0.5 T [1], but in the other case of a MHD power generator, the plasma surely cross over the field of 4 T [2]. For perspective views covering very wide parameters range as above, we have reformulated the field crossing plasma model considering that dissipative process must be most important for stagnating the plasma flow.

We employ the equations of motion about electrons and ions of the form below:

$$\vec{E}+\vec{v}_e\times\vec{B}+\frac{1}{en}\nabla p_e=\eta\vec{j}\ , \tag{1}$$

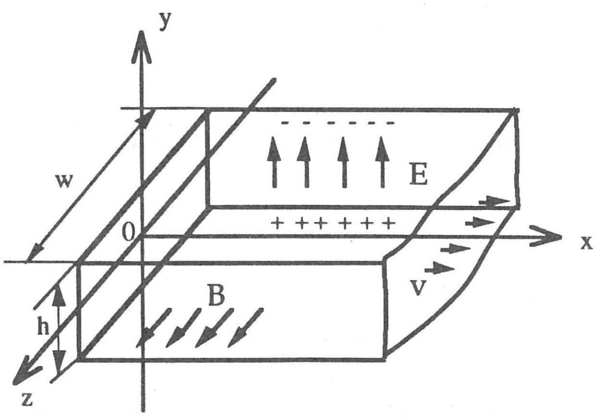

Fig. 1. A slab plasma crossing over the static magnetic field B pointing at z-axis with the flow velocity v

$$\frac{m_i}{e}\frac{d\vec{v}_i}{dt}+\frac{1}{en}\nabla p_i-\left(\vec{E}+\vec{v}_i\times\vec{B}\right)=-\eta\vec{j}\ . \tag{2}$$

The slab geometry in Fig.1 is employed, and we find that if $\vec{E}+\vec{v}_e\times\vec{B}=0$ and $\vec{E}+\vec{v}_i\times\vec{B}=0$ are satisfied along the flow, the ideal cross field motion of the velocity $v_{ix}=v_{ex}=E_y/B$ is achieved. If that were the case, the plasma behaves as if there is no magnetic field because the plasma motion is simply described by

$$nm_i\frac{d\vec{v}_i}{dt}=-\nabla(p_i+p_e)\ . \tag{3}$$

For this ideal state, the polarization $\vec{P}$ appearing on the boundary surfaces plays the essential role since $\vec{E}=-\vec{P}/\varepsilon$ holds. Assume that if the ions and electrons developing $\vec{P}$ are recombined, then the electromotive force by the cross-field plasma motion begins to compensate the loss by generating the charging up current j_c ($=\partial P_y/\partial t$) of y component. As a result of this, E_y is kept almost constant. We note however that the negative j_c yields the plasma decelerating force. And, at the quasi steady state, equation of motion without the pressure term may be given by

$$m_i n v_{ix}\frac{\partial v_{ix}}{\partial x}=j_c B\ . \tag{4}$$

In order to estimate the maximum plasma penetration length L_{max}, we assume the total plasma flux J_p in the equivalent current unit equal to $env_{ix}hw(x)$ is conserved along the flow. Then we have integration of eq.(4) of the form

$$L_{max}=-\frac{2m_iJ_pv_{ix0}}{ehj_cB(w_0+w_{max})}\ , \tag{5}$$

where w_0, w_{max} give the initial plasma width and the final one due to plasma expansion along the field line, respectively. It is seen that large J_p makes the penetration easier. Note that the plasma expansion along the field lines plays the contrary role however.

References
1) Baker, D. A. and Hammel, J. E., Phys. Fluids 8 (1965) 713
2) Brogan, T. R., Advances in Plasma Physics 1 Interscience Publishers, (1968) 227