§19. Inspection on Heating and Sustainment of FRC Plasma by Ion Ring Injection

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A field reversed configuration (FRC) has intrinsic features, i.e. pure poloidal magnetic field confinement, open field configuration outside the separatrix of plasma, and extremely so high plasma beta as 0.9, a value of which is fixed uniquely from the plasma equilibrium condition.

There remain big issues in FRC research, that is, plasma transport, further heating, and sustainment of the configuration. Concerning the plasma transport, we have a conclusion that the mechanism of FRC plasma transport is almost classical. In a case where plasma is so extremely prolong as plasma aspect ratio of ε=15~20 ($\varepsilon=\ell_S/r_S$, ℓ_S is plasma length and r_S is radius), therefore, confinement time obtained in experiments is ($0.3\ \mu r_s^2/4\eta_0$) which is inferred from one-dimensional MHD trnsdport calculation, where η_0 is Spitzer's resistivity [1]. Here, confinement time (decay time) of particle inventory (τ_N) is assumed to be same with that of trapped magnetic flux (τ_ϕ). For arbitrary ε, a ratio h of experimental confinement time to the numerically obtained result is given as following scaling [2],

$$h = 1 + 8\times10^3\left(\frac{r_s}{l_s}\right)^{2.7} = 1 + 1.2\times10^3\ \varepsilon^{-2.7}$$

For smaller ε, a value of h is larger than an unity due to two-dimensional transport effect.

In order to experimentally verify a dependence of the confinement time on ε and electron temperature Te, an experimental apparatus FTHX (FRC Transport and Heating Experiment) was constructed at Osaka university. The purpose of this experiment is to realize a plasma of large ε up to 15 and to further heat plasma electron by the axially injection of intense and long-pulsed ion beam in the energy range of $50keV$ and in the power range of $50MW$ [2]. Used for this injection is a pulse ion diode which is a type of magnetically insulated and geometrically focused.

The first candidate of methods for sustaining the high β configuration of FRC is ion beam injection of MeV which has been used to realize so intense ion-ring as to generate reversed field on the axis in mirror field at Cornell university .

When an ion are injected axially into solenoidal magnetic field (external field of FRC), it start angular motion including the axis on its locus of motion as it raises magnetic potential and its axial speed decreases. In a case where the surface of an ion diode on which the ion is formed is in negative magnetic potential compared to that of the solenoid, the ion rotation is accelerated to encircle the axis and to form an ion ring. Axial motion of the ion ring may be annihilated by auxiliary weak field. Then the ion ring may merge with FRC plasmas and continuously supply reversed magnetic flux into the plasmas. As the axial speed of the ions recovers inside the plasma due to the trapped flux of the plasmas, the ion ring may bounce axially in the plasmas.

This method generates gross rotation of ions inside the plasmas and may cause n=2 rotational instability. It is ,therefore, necessary to make further study on effects of the gross rotation of ions on plasma stability.

Neutralization of space charge in ion beam and annihilation of canceling current of electron were demonstrated in IREX at Cornell University.

Refferences

1) S. HAMADA, Nucl. Fusion,26, 729, 1986.
2) S. OHI, Fusion Technology Transactions, 27, April, 349,1995.

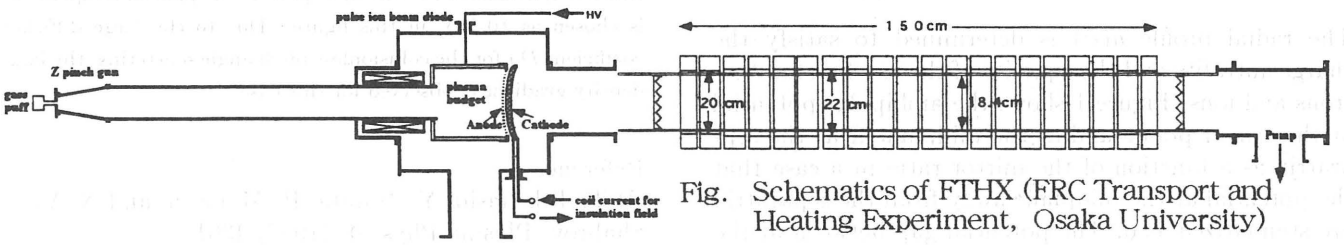

Fig. Schematics of FTHX (FRC Transport and Heating Experiment, Osaka University)