§11. Review of a Required Condition for D-^{3}He Fusion in a Field-reversed Configuration Plasma

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A conceptual design reactor based deuterium-helium3 fueled field-reversed configuration plasma “ARTEMIS” was proposed about 20 years ago [1]. Higher plant efficiency is estimated owing to its lower neutron yield and possibility of direct energy conversion. The energy confinement time required to maintain a burning plasma, however, needs to be longer than 1 sec, and this is much longer than experimental results. Therefore, dominant transport process in an FRC should be studied to modify its confinement properties.

External heating and flux maintenance are also important issues. Neutral beam injection into the FRC plasma is firstly demonstrated at the FIX (FRC Injection Experiment) machine[2]. The FRC lifetime is extended by NBI; it is thought that it results from suppression of a global motion of the FRC by a beam ion ring formed near the X-point[3]. Power deposition by beam ions to the plasma is calculated by tracing orbits of beam ions [4,5]. Since the beam ions are injected obliquely with respect to the geometric axis, they suffer from the end loss significantly. Therefore, the deposition power is at most 10 % of the injection power. Contrary to the axial injection, tangential NBI (TBNI) can suppress orbit losses of beam ions drastically[6]. We study now electron heating by beam ions with Coulomb collisions and flux supply by electron heating. An equilibrium state is calculated by the Grad-Shafranov equation. Neutral beam particles are injected tangentially as shown in Fig. 1. A typical trajectory of 15-keV beam ion in the FRC is drawn in Fig. 2. Electron heating by TNBI is numerically studied and reported in Ref. 6).

The magnetic flux might be maintained by the beam current. However, the resistive force between electrons and beam ions reduces the electron current that is dominant in an FRC. Therefore, numerical calculation of the temporal evolution of the magnetic flux in a neutral beam injected resistive FRC plasma. In particular, effects of the thermal force[7] are studied, because it generates the azimuthal component of electric field that cancels the resistive force. The poloidal magnetic flux profile on the midplane is shown in Fig. 3. For the case of the dashed line in Fig. 3, electrons near the field-null point are heated by TNBI. It is found that electron heating contributes to the flux maintenance. On the other hand, the magnetic flux decays due to resistivity as shown by the dotted line in Fig. 3.

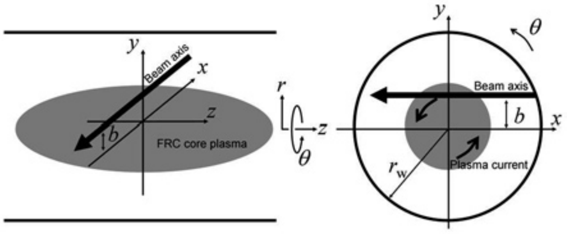

Fig. 1. Geometry of tangential neutral beam injection.

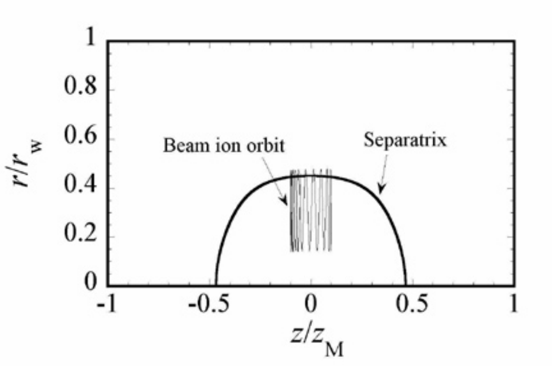

Fig. 2. A typical trajectory of the 15-keV beam ion.

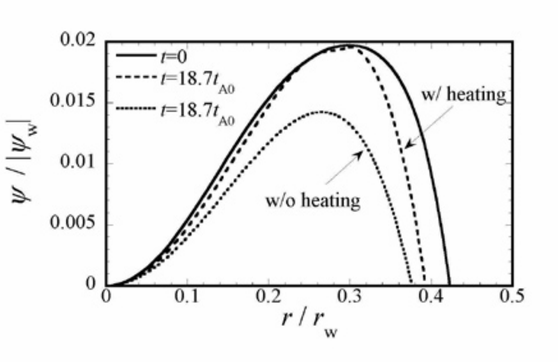

Fig. 3. The magnetic poloidal flux on the midplane (z=0) profiles. The solid line indicates the initial profiles.

We proposed that flux decay causes direct spin-up of an FRC [8] and subsequent rotational instability. Therefore, flux supply will be effective to avoid the global instability. Validity of the direct spin-up model is supported by the rapid loss of electron angular momentum, which is caused by high frequency electromagnetic fluctuation. Experimental detection of the high frequency fluctuation in an FRC is required. Also, numerical calculation of transport coefficients is needed to clarify the dominant transport process. The issues above will be studied in the next year.

1) Momota, H. et al., Fusion Technol. **21**, 2307 (1992).
2) Asai, T. et al., Phys. Plasmas **7**, 2294 (2000).
3) Asai, T. et al., Phys. Plasmas **10**, 3608 (2003).
4) Takahashi, T. et al., Phys. Plasmas **11**, 3131 (2003).
5) Takahashi, T. et al., Phys. Plasmas **11**, 3801 (2003).
6) Takahashi, T. et al., J. Plasma Fusion Res. **81**, 421 (2005).
7) S. I. Braginskii, *Transport Properties in a Plasma,* in Review of Plasma Physics, M.A. Leontovish (ed.), Consultants Bureau, vol. 1, p. 216 (1965).
8) Takahashi, T. et al, PFR **2**, 008 (2007).