§16. Steady-state Operation of Extremely High-beta Torus Plasma

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A field-reversed configuration (FRC) plasma is generally formed using the formation techniques as a field-reversed theta pinch (FRTP), a spheromak merging and a rotationg magnetic filed (RMF). Most of these experiments have no additional heating and current drive method therefore those have been conducted in a pulsed fashion. Then experimental researches of confinement and stability have never been performed. The FRC plasma is the only candidate which can realize a magnetic confinement with approximately 100% of beta value. Then the confined particles have a large normalized Lamor radius inside a separatrix. This condition would be obtained in the burning state in the other torus system with comparatively low beta values. Therefore, as the FRC plasma is a candidate for a high-efficiency fusion reactor core itself, it can also simulate the behavior of α particle in a burning state which cannot be realized on the current stage of tokamak and helical system. This research project has aimed to propose the experimental plan for the steady state operation of the high-beta FRC plasma to realize α particle simulation by using a particle simulation, an equilibrium analysis and a MHD stability analysis based on the experimental database performed in University laboratories.

Source of the toroidal flow which causes destructive rotational instability with toroidal mode number $n = 2$ has been investigated in this fiscal year. Proposed several theoretical scenarios had been given further validation and another possible mechanism of toroidal spin-up has been proposed. This shows that the decay of magnetic flux potentially causes toroidal spin-up of a FRC and the particle simulation of this mechanism indicates the consistency with an experimental result. The simulation also shows the conventional concept of toroidal spin-up due to the end shorting cannot explain the experimental result. Typical calculation results are shown in Fig. 1.

To confirm the simulation results, an ion Doppler measurement system for the spatial distribution of toroidal flow has been developed and the observation has been conducted. The experimental results have been presented in comparison with the particle simulation[1]. Figure 2 shows the typical time evolution of the toroidal rotation of plasma column

Feasibility analysis of steady state operation due to a neutral beam injection (NBI) has also been performed in this project. To evaluate the efficiency of NBI heating, the loss of hot beam ions due to the charge-exchange reaction with a background neutrals were numerically estimated. In this estimation, Monte Carlo method is employed to calculate ionization process and it has realized to simulate NBI efficiency including the charge exchange process along the ion trajectory[2].

Based on these theoretical investigations, experimental plan for the steady state FRC operation has been constructed.

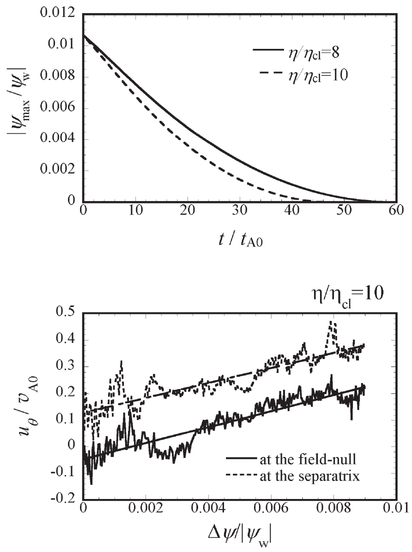

Fig. 1. Time evolutions of trapped flux (top) and toroidal flow velocity (bottom).

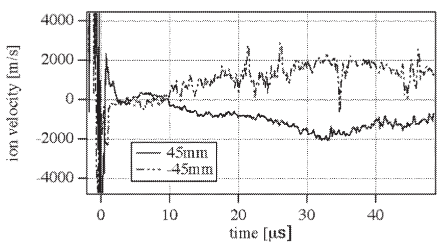

Fig. 2. Time evolution of the maximum poloidal flux measured on the NUCTE-III device.

Reference
1) Asai, T. *et al*, in 48th Annual Meeting of APS-DPP (2006)
2) Takahashi, T. *et al*., J. Plas. Fus. Res. **82**, (2006) 775