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Compact Toroid Injection Fueling on a Large-sized Field-Reversed Configuration

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A repetitively driven compact toroid (CT) injector has been developed for large-sized field-reversed configuration (FRC) facility of the C-2/C-2U primarily for refueling. Pursuit of the FRC as fusion reactor is motivated by highly favorable technological features: extremely high beta (>50%), a natural divertor, and axial mobility allowing separation of start-up and confinement functions. Recently, high confinement performance of FRC has been achieved on the C-2/C-2U facility by neutral beam injection (NBI). However, development of effective fueling method remains as a significant task of FRC fusion reactor core.
A CT is formed and injected by a magnetized coaxial plasma gun (MCPG) exclusively developed for the C-2/C-2U FRC. It consists of a set of coaxial cylindrical electrodes, a bias coil and four gas injection ports which are arranged tangentially on the outer electrode. The inner electrode is coated by tungsten to reduce impurity influx. A plasma ring is generated within a gap between the electrodes and is accelerated by Lorenz self-force. During this acceleration process, toroidal current is induced by a poloidal flux interlinked with the plasma ring. Then, the magnetized spheromak-like CT is ejected from the MCPG.
To refuel the particles of long-lived FRCs, multiple CT injection is required. Thus, a multi-stage discharge circuit has been developed for multi-pulsed CT injection. Drive frequency of this system can be adjusted up to 1 kHz and the number of CT shots per injector is 2; the system can be further upgraded for larger number of injection pulses. The developed MCPG has achieved supersonic ejection velocity in the range of ˜100 km/s. Key plasma parameters of electron density, electron temperature and the number of particles are ˜ 5 × 10ˆ21 mˆ-3, ˜ 40 eV, and 0.5 - 1.0 × 10ˆ19, respectively.
In this project, single and double pulsed CT injection fueling have been conducted on the C-2/C-2U facility by two CT injectors. The CT injectors are mounted 1 m apart on the vicinity of midplane. To avoid disruptive perturbation on the FRC, the CT injectors have been operated at the lower limit of particle inventory. The experiments demonstrated successful fueling with significant density build-up of 20 - 30% of the FRC particle inventory per single CT injection without any deleterious effects on the C-2/C-2U FRC.

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