§18. Characteristics of High-Beta and High-Elongation Spherical Tokamak Like Field-Reversed Configuration

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A field-reversed configuration (FRC) has been known as an extremely high-beta compact toroid which is confined purely with poloidal magnetic field. The FRC is known as a torus confinement system naturally at the highest limit of pressure gradient in the second stability of ballooning mode instability.

The configuration of FRC which is locally added toroidal magnetic flux is expected to be relaxed into a highbeta (nearly 100%) and high ellipticity (has extremely high q value in vicinity of separatrix) spherical tokamak (ST) like configuration¹⁾. The techniques to form ST-like FRC have been demonstrated in experiments of a spheromak merging, a field-reversed theta-pinch and a helicity injection into a FRTP-FRC²⁾. Furthermore, it has been reported that a highbeta stable ST-like FRC configuration is spontaneously formed in a fast translation experiment of FRTP-FRC^{1,2)}.

In this work, for a cross-section study of high-beta toroidal confinement system, we propose and experimentally demonstrate a novel method to generate A ST-like FRC from highly-elongated high-beta FRC. To investigate the property of the ST-like FRC especially transited from high-beta FRC side, a new facility of FRC translation experiments, FAT (FRC Amplification via Translation) has begun operations.

The FAT facility has a quasi-cylindrical confinement region with a large bore quartz tube, i.e. high aspect-ratio (low length-to-diameter ratio) compared with a conventional FRC as shown in Fig. 1. The confinement region has a center solenoid coil on the geometrical axis. A simply-connected FRC formed in the theta-pinch formation region is translated into the confinement region with the translation velocity of 100 - 200km/s, then relaxed into a torus shape.



Fig. 1. Schematic view of FAT facility with a center solenoid and conductor (top) and magnetic field profile on the geometrical axis.



Fig. 2. Trapped poloidal magnetic flux of translated FRCs in the formation region. From the left, early phase and after the translation process, respectively.

In the initial series of experiments, it was demonstrated that the translated plasmoid becomes a quiescent FRC without disruption through the dynamic translation process with rapid radial expansion ^{3, 4}. Also mass dependency of the equivalent NBI (neutral beam injection) effect⁵ has been demonstrated in the translation experiments into the confinement chamber filled with deuterium and hydrogen gas⁶. Figure of 2 indicates a recover of polodal flux after the first reflection by the equivalent NBI effect.

Furthermore, development of formation technique has been conducted in the theta-pinch formation region. Theta-pinch FRC formation has been demonstrated with thin (4mm in diameter) stainless steel center conductor in the case of 6mT bias field, 0.18T main compression field and the center conductor current of 1kA. The successful formation of FRC with the electron density of $\sim 10^{20}/m^3$, a plasma radius of 4cm and an elongation of 10, has been demonstrated. The magnetic structure of ST-like FRC is confirmed by the internal magnetic field measurement.

This study was supported by NIFS under contract No.NIFS13KBAP017.

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