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Formation of a Field-Reversed Configuration by Negative Biased Conical Theta Pinch

逆バイアス円錐θピンチによる磁場反転配位プラズマ生成

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New formation method for a field-reversed configuration (FRC), which is based on negative biased theta pinch method, is proposed using conical and cylindrical theta pinch coil. An FRC-like and a spheromak-like compact toroids are formed in the cylindrical and the conical theta pinch, respectively. A higher performance FRC will be produced using a coalescence of the each compact toroid by installed auxiliary coils in the hybrid coil. Behavior of the both compact toroid in the theta pinch coils are investigated experimentally and a sequence control of the coil system is examined.

1. Introduction

Controlled thermonuclear fusion has a large potential of a sustainable energy technology. Especially, an advance fusion, D-^{3}He or p-^{11}B fusion, at all., which is referred to as an aneutronic Fusion, has enormous properties for resolution of global environmental problems. To make the advanced fusion possible, improvement of high beta magnetic confinement system, which is a field -reversed configuration (FRC) and a spheromak (SHP), is necessary.

Recently, the confinement properties of FRC plasma have been improved. A large theta pinch merging system, C-2 on Tri Alpha Energy Inc., was built to form high flux (~15 mWb) and hot (>0.5keV) FRCs using a collision-merging technique. Stable, long-lived FRC plasmas have been achieved in this device with record configuration lifetime of over 2ms [1]. Active of control of destructive rotational instability for FRC plasmas has been demonstrated in NUCTE III device on Nihon University, using double-sided plasmoid (SPH-like compact toroid) injection technique [2]. The elliptical deformation of the cross-section was mitigated as a result of substantial suppression of spontaneous spin-up by the injection. It was found that the injected plasmoid provided better stability against the rotational mode, suggesting that the compensation of the FRC's decaying magnetic flux might help to suppress its spin-up.

According to the above two experimental results, we propose the new formation method of high performer FRCs. FRC-like and SPH-like compact toroids (CT) are formed in cylindrical and conical theta pinch coils, respectively (Fig.1 of ①). Using merging technique, each CT coalesces in the hybrid coil and high performer FRC with net toroidal field and poloidal flow will be produced (Fig.1 of ② and ③). The behavior of CT plasma formed in the cylindrical and conical theta pinch coils are investigated experimentally to examine the control sequence of the auxiliary coil operation using FRTP method. These CTs is formed by a negative biased theta pinch method because of the possibility of high density and temperature plasma formation.

Table I. Family of Compact Toroid

	Magnetic Structure (B)	Flow Structure (V)
FRC-like	$B_p >> B_t$	V_t only
SPH-like	$B_p \cong B_t$	V_t , V_p

Super-script of "p" and "t" indicate poloidal and toroidal directions

2. New Formation Method for FRC

There are two type of compact toroid shown in Table 1. FRC-like CTs are confined by only B_p ($B_p >> B_t \sim 0$). Strong toroidal flow (~7km/s at the magnetic axis and t=20 μs) appears spontaneously in theta-pinch formed FRC-like CTs [3]. SPH-like CTs have the both components magnetic field and the plasma flow (poloidal "p" and toroidal "t") components). The magnitudes of the both

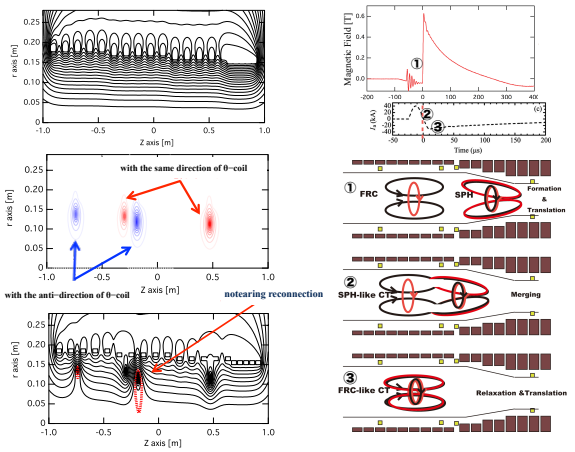

Fig. 1 Conceptual Diagram of Proposed new CT Formation Method.(

components of magnetic field are almost equal and in the conical theta pinch formed SHP-like CTs have a strong poloidal flow of V_p~50km/s, especially [4,5]. The addition of toroidal field and toroidal or poloidal flow to FRC-like CTs induces the self-organization and two fluid effects to improve the confinement properties and the suppression of the spontaneous rotation [6].

Figure 1 shows the conceptual diagram of the proposed new formation method of high performance FRC. The hybrid theta pinch coil consists of cylindrical and conical sections. In the each section, auxiliary coils are installed to control magnetic reconnections of each formation phase and axial motions of each CT.

To examine a sequence control of the hybrid coil and the auxiliary coils, behavior of the CT plasmas formed in the cylindrical and conical theta pinch on NUCTE device. The cylindrical theta pinch coil consists of 18 segment coils of r_c=0.17 m at center region and 5 segment coils of r_c=0.15 m at the both end of the center region with mirror ratio of about 1.2. The conical theta pinch coil does several segment ones of r_c=0.18 m, 0.17 m, 0.16 m and 0.15 m with the equivalent corn angle of 1 degree. The ration of the magnetic field strength at r_c=0.18 m to that of r_c=0.15 m, is about 1.4. The magnetic field at the midplane is the peak reversed compression field of about 0.55 T and that of the bias field of about 32 mT. A closed magnetic configuration is made by a tearing magnetic reconnection in these experiments. In Table 2, the summary of the CTs plasma behavior, which is the magnetic reconnection time (τ_R), the onset time of the axial contraction (τ_{ax}), the direction of axial motion at the both ends and the velocity of the axial motion V_{ax} are indicated.

From these experiment results, the formation

Table II. Summary of CT Behavior formed in cylindrical and conical theta pinch coil.

Coil type	Cylindrical	Conical
τ_R [μs]	Uniform ~4μs (r_c: 0.15m)	~3μs (r_c: 0.15 m) 5μs (r_c: 0.18 m)
τ_{ax} [μs]	~5 μs	~4 μs (r_c:0.15m)
Axial motion	To midplane at the both sides	From r_c=0.15m to r_c=0.17m
V_{ax}	~0	80 km/s

time of CTs in the conical theta pinch are faster than that of cylindrical one. It is necessary to slow down the onset time of the coalescence process than that of axial contraction of the both CT. To control the reconnection time of the mid plane sides, using auxiliary coils, the bias field of a cusp profile are made and no-tearing magnetic reconnection are triggered at the positions, shown in Fig.1 of the lift side. Upon the completion of the reconnection, the auxiliary coils are operated to merge the CTs with each other, shown in Fig. 1 of the right side [10].

3. Summary

The new formation method for the high performance FRC plasma, using the coalescence technique of FRC-like and SHP-like CTs, is proposed. The sequence control of the hybrid coils, which consist of the cylindrical, conical and auxiliary coils, is examined. In near future, the proposed method will be demonstrated experimentally and the improved confinement properties will be reveled.

Acknowledgments

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