§ 16. Simulation Study of Magnetic Helicity Injection into Fusion Plasmas

Suzuki, Y., Kagei, Y. (JAERI-Naka)
Hayashi, T., Mizuguchi, N.

Magnetic helicity injection using coaxial electrodes (Coaxial Helicity Injection: CHI) has successfully demonstrated the non-inductive current generation on HIT-II and NSTX spherical torus (ST) devices [1], however, it is not still evident if closed flux surfaces are produced. Since closed flux is surrounded by open flux linking coaxial electrodes, large fluctuations have been observed in the core, which makes it difficult to conclude the presence of closed flux surfaces. On the other hand, another novel ST configuration in CHI-driven systems, called "flipped ST", has first been formed and sustained in the HIST device [2]. It is characterized by opposite polarity to normal ST in closed flux surfaces. Since in the flipped state the closed flux is isolated from the open flux, closed flux is expected to be form without large global fluctuations. In order to investigate such a favorable configuration, numerical experiments using 3-D MHD simulations are executed. In this work, we pay attention to the formation process of the flipped configuration.

The simulation region consists of two cylinders with the center post. One is a gun region, where the bias magnetic flux penetrates inner and outer boundaries in the radial direction corresponding to a pair of electrodes. The other is a confinement region, whose boundaries are assumed to be a perfectly conducting wall. The initial magnetic state is a normal ST configuration given by solving the Grad-Shafranov equations numerically under such boundary conditions. The simulation starts running when the toroidal magnetic field on the center post starts to reverse.

Our simulation demonstrates the formation of a flipped ST configuration accompanied by a spontaneous reversal of the magnetic polarity [3]. The time evolutions of magnetic fields are shown in Fig. 1. After the toroidal magnetic field on the center post is reversed at $t/\tau_A = 100$, where τ_A is the Alfvén transit time, a large distortion of fields is seen at $t/\tau_A = 117$ (b). A sudden change in the path of open field lines means that the magnetic reconnection between open and closed field lines takes place. As the reconnection events collapse initial flux surfaces, not only the direction of toroidal magnetic field but also that of poloidal magnetic field (that is, toroidal current) is reversed at $t/\tau_A = 222$ (c). The reconnection process proceeds and an axisymmetric steady flipped configuration has been established at $t/\tau_A = 820$ (d). This behavior well reproduces the observations.

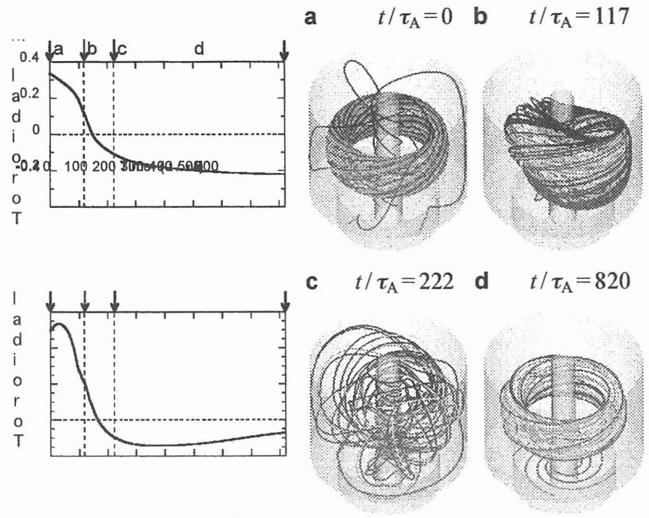

Fig. 1. Time evolutions of magnetic flux, current and magnetic field lines during the self-reversal of magnetic polarity. Initial normal ST (a) relaxes toward the flipped state (d) through the deformation (b) and the collapse of initial flux surfaces (c) due to the magnetic reconnection event.

References

1) Jarboe, T. R. et al.: 19th IAEA Fusion Energy Conf., Lyon, (2002) IAEA-CN-94/IC/P-10.
2) Nagata, M. et al.: Phys. Rev. Lett. **90** (2003) 225001.
3) Kagei, Y. et al.: Plasma Phys. Control. Fusion **45** (2003) L17.