§12. Simulation Study of Magnetic Helicity Injection into Fusion Plasma

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i) Introduction

Electrostatic helicity injection from a magnetized coaxial source into fusion plasma is expected to be the most attractive current drive method for low aspect ratio fusion devices. In several existing devices coaxial helicity injection (CHI) has successfully demonstrated the formation and sustainment of spheromak/spherical tokamak plasmas without Ohmic induction through its self-organizing process[1)-3)]. However their physical mechanism has not been well understood. To reveal this, three-dimensional One-fluid magnetohydrodynamic (MHD) numerical simulations are executed. In this work, we pay attention to spheromak plasmas.

ii) Simulation model

The simulation domain consists of two cylindrical regions, which are coaxially connected with each other. One is an injector 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 the perfect conducting wall. The initial magnetic configuration is given by solving the Grad-Shafranov equation numerically under such boundary conditions. Simulations are started by the increase of a toroidally symmetric tangential electric field (poloidal current) on the nonelectrode surface, which corresponds to helicity injection.

iii) Simulation results

Typical simulation results exhibit the amplification and sustainment of the toroidal current as shown in Fig.1 (a). In addition, the periodic behavior of time evolution of the toroidal current synchronizes with that of the n = 1 mode magnetic energy (Fig.1 (b)), namely the toroidal current increases when the n = 1 mode magnetic energy decreases. In Figure 2, we can see that the rotating n = 1 helical kink deformation of the field lines around the geometric axis occurs, which causes the increase of the n = 1 mode magnetic energy. After that the magnetic reconnection event takes place, which causes the decrease of the n = 1 mode energy. We observe these phenomena repeat periodically. Therefore it is considered that magnetic reconnection plays a major role to convert the externally injected poloidal current to the toroidal current, which results in the sustainment of spheromak plasmas.

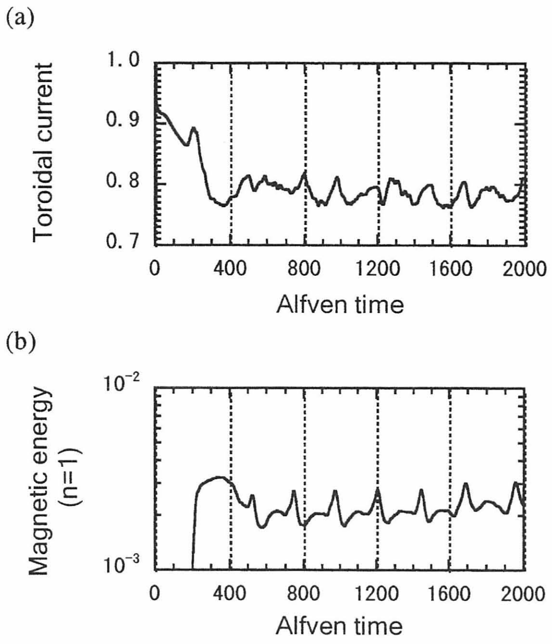

Fig.1 Time evolution of the toroidal current (a) and of the n = 1 mode magnetic energy (b). n is the toroidal mode number.

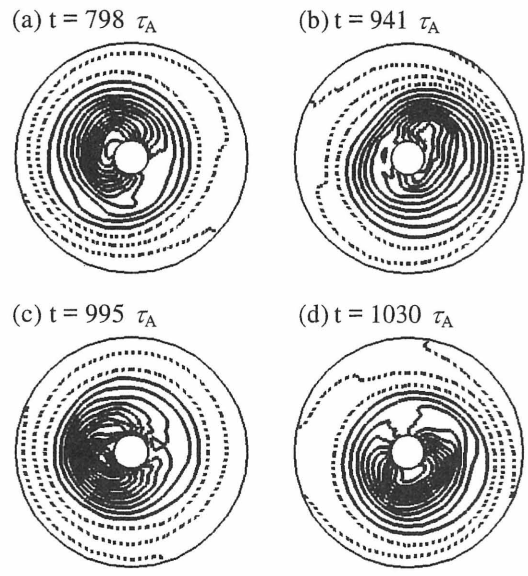

Fig.2 Time evolution of contours of B_z (solid ones for positive, dashed ones for negative) on the toroidal cross section during the reconnection process.

iv) Reference

1) Nagata, M. et al.: 17th IAEA Fusion Energy Conf., Yokohama, IAEA-CN69/EXP4/10 (1998).
2) S. Woodruff et al.: Proc. 27th EPS Conf. Control. Fusion Plasma Phys., Budapest, ECA 24B(2000) 1344.
3) R. Raman et al.: Plasma Phys. Control. Fusion 43(2001) 305.