§31. Simulation Modeling for Formation of High Beta Field-reversed Configuration

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Extremely high-beta field-reversed configuration (FRC) plasmas are sustained by diamagnetic plasma current which is orthogonal to the magnetic field. Conventionally, the field reversed theta pinch (FRTP) method is employed to form FRC plasmas, and relatively rapid process and inductive electric field in the toroidal direction are believed to be essential for forming FRC plasmas. Since the presence of a pressure gradient, however, naturally produces the diamagnetic current[1)], faster plasma supply than diffusion process may be possible to cause the field reversal and to make FRC plasmas. Here, we carry out the 3-dimensional hybrid simulation to study feasibility of FRC formation by continuous plasma feeding instead of the FRTP method.

Let us suppose a uniform magnetic field is in the axial direction at the initial time. We load plasma particles so as to form the Gaussian distribution in the *x*-*y* plane as shown in Fig. 1. The particles are also in the Gaussian profile in the axial direction within a thin layer. When the plasma particles distribute in the ring shape with a radius of field-null circle as seen in a FRC plasma, the direction of pressure gradient near the outer region of the ring is opposite to inner one. The opposite diamagnetic current causes the active instability that destroys an axisymmetric ring-shape profile. Therefore, we consider here the plasma fuelling in a manner as Fig. 1. The particle fuelling rate is determined to compensate the axial loss along the magnetic field line. The present calculation parameters are listed in Table 1.

The ion density and axial magnetic field profiles in the y direction are presented in Fig. 2, where n_{max} is $1.6\times10^{22}\,[\mathrm{m}^{-3}]$. The peak value gradually increases before reaching a balanced state at 2.5 μs. A quasi-steady state lasts from 2.5 μs to 5.0 μs, because the density profile is unchanged in this duration. After 5.0 μs, however, we can see rapid decrease which implies the significant axial end loss. The magnetic field near the geometric axis is weakened due to the toroidal electric field given by

$$E_\theta = -u_{\mathrm{ez}} B_r + u_{\mathrm{er}} B_z + \eta\, j_\theta \,. \qquad (1)$$

The field reversal, however, never be obtained by our 3-d hybrid simulation. Hence, in the present calculation condition, FRC plasmas never be formed by the continuous plasma feeding. The second term of Eq. (1) is dominant to reverse the magnetic field, where the magnetic field itself is involved. Therefore, as the strength of magnetic field goes to zero, its decreasing rate also vanishes; it constricts the field reversal.

In our present scheme, we tried to cause field reversal where the external magnetic field is fixed. In this case, it is impossible to cause radial compression by the electric drift due to the toroidal inductive electric field and axial magnetic field. On the other hand, the external field is reversed in the conventional FRTP method; this can cause successfully radial compression of a plasma, which is so called the theta pinch.

1) Hirano, K.: Nucl. Fusion **24** (1984) 1159.

Table 1. Calculation parameters

External magnetic field	0.4	[T]
Ion temperature	50	[eV]
Electron temperature	50	[eV]
Particle fuelling time	5.0	[μs]
Particle fuelling rate	1.4×10^{26}	[1/s]

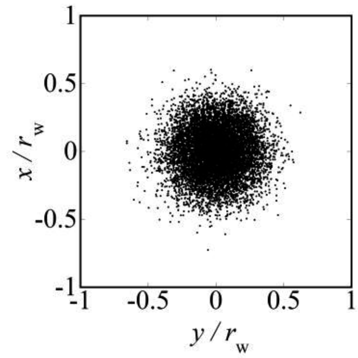

Fig. 1. Initial ion distribution on the *x*-*y* plane.

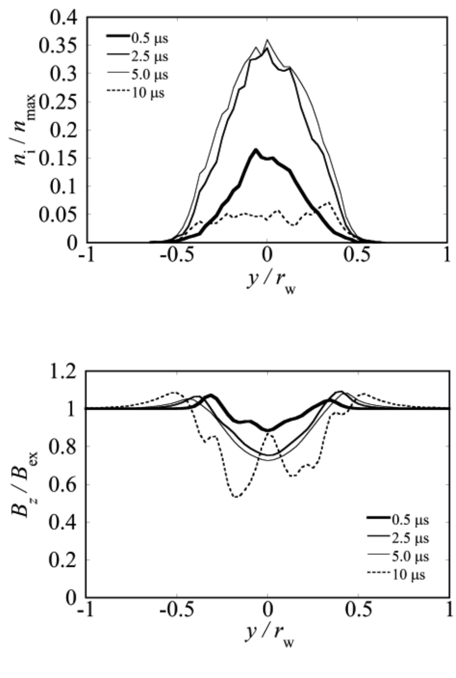

Fig. 2. Temporal changes of the profile of (Top) the ion density and (Bottom) the magnetic field.