§15. Three Dimensional Gyrokinetic Particle Simulation of Tokamak Plasmas

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Three dimensional gyrokinetic particle simulation[1] was done to study the ideal internal kink mode and the following full reconnection process in a tokamak. The numerical model is a straight tokamak with a rectangular cross section. Strong and uniform (toroidal) magnetic field is in z direction. Periodic end condition is used in z. The system is bounded by the perfectly conducting wall. The selfconsistent (poloidal) magnetic field in the x and y direction is generated by the electron and ion currents along the magnetic field. Electron and ion dynamics parallel to the magnetic field are followed as well as the $\boldsymbol{E} \times \boldsymbol{B}$ drifts. The electrostatic potential is caluculated from a gyrokinetic Poisson equation which includes ion polarization effects. The z component of the vector potential is calculated by Ampere's law. Because a formulation using a canonical momentum is used, inductive electric field is not appear explicitly in the code. To reduce the CPU time, gyroaverage was not implemented for ions.

Fig. 1 shows an example of the time evolution of the magnetic field structure. The number of electrons is 8388608. Also, the same number of ions are used. The CPU time is about 21 hours on SX-3/24R for 2000 time steps run. We used such a large number of particles to clearly observe the time evolution in the linear stage. The system size is $L_x \times L_y \times L_z = 64 \times 64 \times 32$, where z direction is stretched by a factor of 1000. The initial q value on the magnetic axis is set to be 0.85. The time step size is $3200\omega_{pe}^{-1}$. Here, m and n represents poloidal and toroidal mode numbers, respectively. Only $n = -1, 0, 1$ modes are included in the simulation. The $m = 1$ island around the $q = 1$ magnetic surface grows and push the core plasma including the magnetic axis toward the directon of the wall. Finally, the original magnetic axis disappears and the $m = 1$ island forms a new core plasma. We believe that the collisionless process (electron inertia) is responsible for the full reconnection process occuring in the simulation. The reason is that the full reconnection time and the width of the negative current layer about the x point is of the same order of the Wesson's predicton. In the Wesson's theory, the width of the current layer is of the order of the collisionless skin depth of electrons.

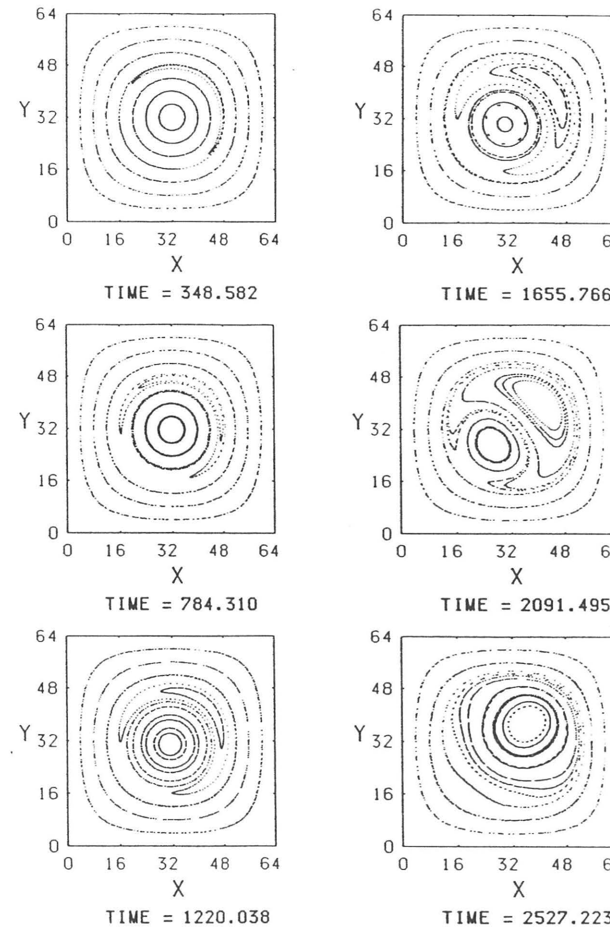

Fig. 1. Mapping of Magnetic Field Lines.

References

1) Naitou, H., Journal of Plasma and Fusion Research 70 (1994) 135.