§20. Gyrokinetic Particle Simulation of Internal Kink Modes

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Internal disruption in a tokamak has been simulated using a three-dimensional magneto-inductive gyrokinetic particle code[1]. The code operates in both the standard gyrokinetic mode (total-f code) and the fully nonlinear characteristic mode (δf code). The latter, a recent addition, is a quiet low noise algorithm. The computational model represents a straight tokamak with periodic boundary conditions in the toroidal direction. The plasma is initially uniformly distributed in a square cross section with perfectly conducting walls. The linear mode structure of an unstable $m = 1$ (poloidal) and $n = 1$ (toroidal) kinetic internal kink mode is clearly observed, especially in the δf code. The width of the current layer around the x-point where magnetic reconnection occurs, is found to be close to the collisionless electron skin depth, which is consistent with the theory in which electron inertia has a dominant role. The nonlinear behavior of the mode is found to be quite similar for both codes. Full reconnection in the Alfven time scale is observed along with the electrostatic potential structures created during the full reconnection phase.

Figs.1 and 2 show the nonlinear phenomena after the full reconnection phase. The Roman numerals in the figures correspond to the different stages of the development. It is clear that the potential profile created in the full reconnection phase survives for a longer time. Due to the $E \times B$ motion driven by this potential, the plasma in the peripheral region at the opposite side of the original x-point comes into the core region. The magnetic reconnection again forms the new core plasma. The central q value now becomes 0.95, which is below unity but is higher than the initial value of 0.85. These results are similar to the results of Biskamp and Drake[2].

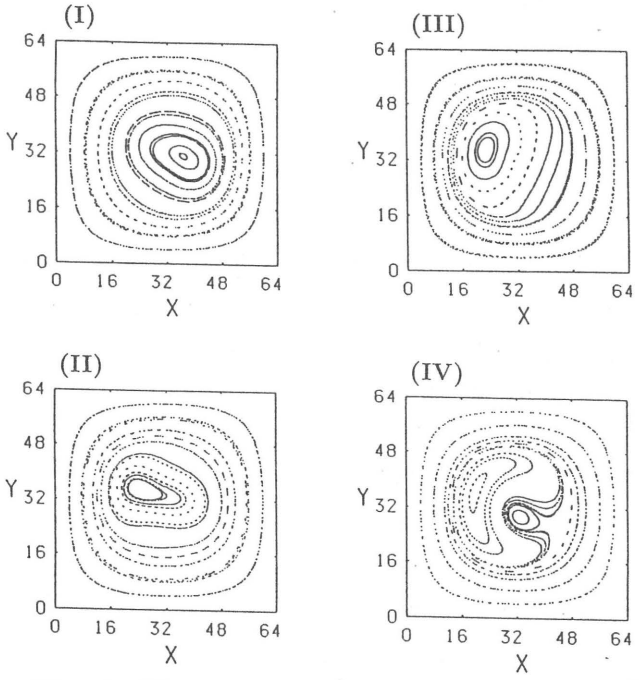

Fig. 1. The magnetic field structure at $z = 0$ after the full reconnection phase. δf code with $n = 0, \pm 1, \pm 2$ modes.

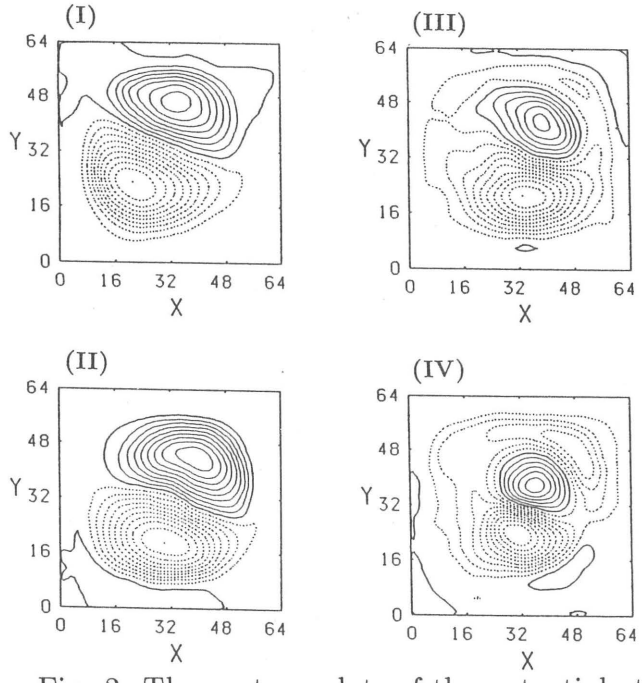

Fig. 2. The contour plots of the potential at $z = 0$ after the full reconnection phase. δf code with $n = 0, \pm 1, \pm 2$ modes.

References

1) Naitou, H., Journal of Plasma and Fusion Research 70 (1994) 135.
1) Biskamp, D., Drake, J.F., Phys. Rev. Letters, 73 (1994) 971.