§6. Nonlinear Simulation of Electromagnetic Current-Diffusive Interchange Mode Turbulence

M. Yagi, S.-I. Itoh (Kyushu Univ.)
K. Itoh

Nonlinear instability mechanism through the enhanced current diffusivity has important role in the confined plasmas. Theory and simulation in the electrostatic limit have been developed, and study of the L-mode and improved confinement has been progressed [1]. At the same time, the understanding of the beta-limit phenomena requires the investigation of the electromagnetic turbulence. Analytic work has suggested an enhanced transport beyond the critical pressure gradient [2]. In order to study the nonlinear electromagnetic turbulence, direct simulation is initiated.

Reduced set of equations are used for the slab plasma within the sheared magnetic field. Constant bad curvature and pressure gradient are taken into account. Basic set of equations for (ϕ, A, p_e, p_i) are given as

$$\begin{aligned} d\nabla_{\perp}^2\phi/dt - [A, \nabla_{\perp}^2A] \\ = -ik_{\parallel}\nabla_{\perp}^2A - ik_y(\alpha_e p_e + \alpha_i p_i) + \mu_c \nabla_{\perp}^4\phi \end{aligned} \quad (1)$$

$$d\nabla_{\perp}^2A/dt - \xi_e[A, \nabla_{\perp}^2A] = ik_{\parallel}\phi + \lambda_c \nabla_{\perp}^4A \quad (2)$$

$$dp_e/dt - \xi_e[A, p_e] = -ik_y\phi + \chi_c \nabla_{\perp}^2 p_e \quad (3)$$

$$dp_i/dt = -ik_y\phi + \chi_c \nabla_{\perp}^2 p_i \quad (4)$$

where $d/dt = \partial/\partial t + [\phi,]$, the operator $[,]$ is the Poisson bracket and α denotes driving force.

The x-axis is taken in the direction of pressure gradient, and other notation and normalization are the ones used in [1]. The parameter ξ_e is in proportion to the ratio of thermal velocity to the Alfvén velocity, and vanishes in the limit where the transport by the magnetic braiding is absent. In electrostatic limit, the responses of ions and electrons are identical, and Eqs.(1)-(4) reduces to the three field model in [1] with $\alpha = \alpha_e + \alpha_i$.

In the presence of the nonlinear interactions in the Ohm's law, Eq.(2), the nonlinear instability takes place if the amplitude exceeds the threshold level. The situation is unchanged both in the electrostatic limit and electromagnetic case. Noticeable difference appears in the level of the saturation level. When the electromagnetic nonlinearity exists in the Ohm's law, i.e., the magnetic turbulence dominates, the selective scattering on electrons is caused. The stabilization effect in the vorticity equation (1) occurs through the ion dynamics, which is weaker than the nonlinear effect in Ohm's law. The turbulent transport coefficients in the simulation for electrons and ions are compared. The electron transport is confirmed to be larger than that of ions by direct numerical simulation. The enhanced transport coefficient in the high- β limit of plasmas is confirmed by simulation.

In the high- β plasma above threshold condition, more stronger power degradation of energy confinement, $\tau_E \propto P_T^{-7/9}$, is predicted.

This study is performed by using the SX-3 super computer at NIFS.

1) M. Yagi, et al., Phys. Plasmas 2 (1995) 4140.

2) K. Itoh, et al., Plasma Phys. Contr. Fusion 37 (1995) 707.