§33. Gyrokinetic Particle Simulation of ETG Mode in Negative Shear Tokamaks

Wakatani, M., Idomura, Y. (Grad. School of Energy Sci., Kyoto Univ.)

We have studied nonlinear dynamics of the ETG (electron temperature gradient) turbulence using a gyrokinetic finite element PIC code developed at Kyoto University. In a negative-sheared slab configuration, simulations are performed for non-resonant single-helicity perturbations, because the nonresonant NS (negative shear)-ETG mode is considered to play a significant role in the electron anomalous transport based on the mixing length estimate [1]. The principal results observed in the nonlinear simulation of the nonresonant NS-ETG mode are summarized as follows: (a) in the linear growth phase, a radially elongated vortex structure predicted by the linear theory appears, (b) in the initial saturation phase, a saturation of the ETG mode is produced by an inverse (normal) wave energy cascade in the $k_y(k_x)$ space, which tends to generate $E \times B$ shear flow, (c) after the saturation of the ETG mode, the secondary instability followed by a generation of the $E_r \times B$ zonal flows occurs and the $E_r \times B$ zonal flow region is extended in the radial direction, and (d) in the quasi-stationary phase, the quasi-steady $E_r \times B$ zonal flows, which are stable to the K-H (Kelvin-Helmholtz) mode, is sustained, and a remarkable reduction of χ_e (electron thermal transport) is observed in the $E_r \times B$ zonal flow region.

The observed $E_r \times B$ zonal flow profile has a large amplitude $v_{E_r \times B} \sim 0.015 v_{T_i}$ only in finite magnetic shear region in both sides of the q_{min}-surface, although an inverse energy cascade in the k_y space is observed also in a region of the q_{min}-surface. Thus, the $E_r \times B$ zonal flow profile is closely related to the q-profile. From the linear stability analysis of the K-H mode, it is found that the parallel electron dynamics, which comes from an effect of the magnetic shear, has a stabilizing effect on the K-H mode. The observed $E_r \times B$ zonal flow profile may be explained by the local critical $E_r \times B$ flow velocity determined by the magnetic shear or the finite $k_{||}$ stabilization. It is considered that the K-H mode play a critical role in the formation of the $E_r \times B$ zonal flow in the ETG turbulence.

In the numerical result shown in Fig.1, the quasi-steady $E_r \times B$ zonal flow decays by changing the q-profile to reduce the magnetic shear. This result indicate that the K-H mode plays a role to destroy the $E_r \times B$ zonal flow in a collisionless plasma. Thus it is considered that a quasi-steady $E_r \times B$ zonal flow is determined by a competition between a flow generation process due to an inverse energy cascade in the k_y space and a flow destruction due to the K-H mode.

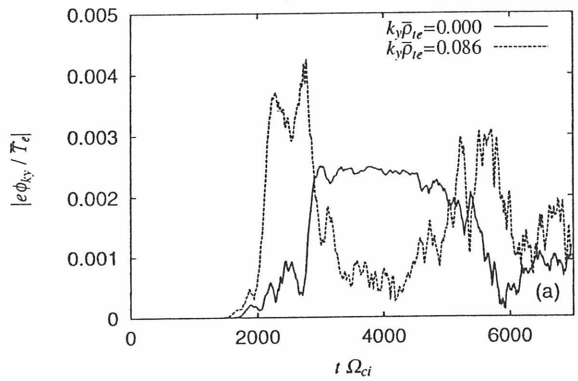

Fig.1. Time history of the k_y of electrostatic potential fluctuations, which is averaged over the $E_r \times B$ zonal flow region. Here the zonal flow ($k_y \rho_{te} = 0$) and the dominant fluctuation ($k_y \rho_{te} = 0.086$) are shown. The q-profile is changed from $L_{ne}/L_{ns} = 0.609$ to $L_{ne}/L_{ns} = 0.304$ at $t\Omega_i = 4.183$, where $L_{ne}(L_{ns} = \sqrt{(2q_{\mathrm{min}}^2 R)/(q''_{\mathrm{min}} r_{\mathrm{min}})})$ is a characteristic length of density gradient (magnetic shear).

Reference

1) Idomura, Y., Tokuda, S. and Wakatani, M., to be published in Phys. Plasmas **7** (2000)