§20. Simulation of Resistive Drift Wave Turbulence in Cylindrical Plasmas

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Turbulent plasmas form a variety of structures, and researches have been carried out to clarify their role in plasma transport. Recently, plasma experiments in a simple linear configuration have been revisited for quantitative understandings of the structural formation mechanism by turbulence $^{1)}$. The common process of nonlinear saturation in magnetized plasmas can be deduced, so the detailed simulation study of drift wave turbulence in a linear device has great importance to clarify the turbulent structural formation mechanism.

We have been developing a 3-D numerical simulation code called ‘Numerical Linear Device’ (NLD), which describes the resistive drift wave turbulence in a linear device $^{2)}$. The three-field (density, potential and parallel velocity of electrons) reduced fluid model is adopted. The plasma has a simple cylindrical shape, and the magnetic field has only the component in the axial direction with the uniform intensity. According to experiments, high density ($n_e > 1\times10^{19}$[m^{-3}]) and low temperature ($T_e < 5$ [eV]) plasmas in an argon discharge are analyzed. The density of neutral particles is high even in the plasma core region, so the effect of neutral particles is taken into consideration.

A nonlinear simulation has been performed to examine the saturation mechanism of the resistive drift wave turbulence. A resistive drift wave can be excited with a small ion-neutral collision frequency, and is saturated by nonlinear coupling. Two dominant mechanisms, the quasi-linear effect of density flattening, and the modification of the electrostatic potential profiles were found to play an important role in the saturations of turbulence $^{3)}$.

The density flattening is induced by nonlinear mode coupling. The $(m, n) = (0, 0)$ mode is excited and contributes to the background density profile, where m and n are the azimuthal and axial mode number, respectively. After the quasi-linear flattening of the density profile occurs, the density gradient is not large enough to drive the instability any more, so that all modes except the (0, 0) mode are damped in the case with relaxation of the background density profile. In this way, zonal structure formation of N gives rise to stabilization of the system.

If the density gradient is sustained, the mean ($m = n = 0$) potential plays an important role in the steady turbulence. Steady turbulence with intermittent growth of the fluctuations is attained with a fixed density profile. The formed self-sustained potential structure shows oscillation in amplitude as in Fig. 1 (a). The fluctuation amplitudes of the internal energy of $(m, n) \neq (0, 0)$ modes simultaneously oscillate in time, showing high correlation with the (0, 0) mode of the potential (Fig. 1 (b)). Using the mean potential profiles and the fixed background density profile, the instantaneous linear growth rate is calculated (Fig. 1 (c)). The time evolution of the instantaneous linear growth rate also shows oscillation, and the tendency agrees with the increase and decrease phase of the mode energy. This saturation takes place by the energy exchange between the $(m, n) = (0, 0)$ mode and most unstable modes. The growth of the unstable modes leads ϕ_{00} formation by nonlinear coupling. This potential stabilizes the modes. Once the fluctuation is quenched, the source for ϕ_{00} generation disappears and ϕ_{00} is damped by neutral collisions. Damping of ϕ_{00} mode makes the system linearly unstable, and then the modes start to grow again. In this way, the limit cycle oscillation dictated by ϕ_{00} takes place. It is found that the parallel structure is important because the parallel derivative of the current is dominant in the nonlinear terms included in the evolution equation of the potential.

In this way, nonlinear simulations clarify the stabilizing effects of the quasi-linear flattening of the density profile and of the generated mean potential profile. Contours of fluctuations are strongly twisted in the nonlinear coupling phase in the simulations, which corresponds to the generation of the momentum transport. The measurements in multiple positions reveal the spatial structure of nonlinear coupling and the comparisons with the numerical simulations give the quantitative evaluation of the balance of momentum transport.

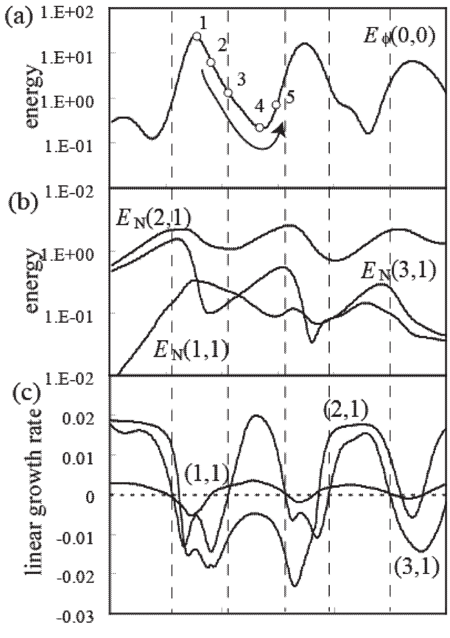

Fig.1: Time evolution of (a) the electric field energy $E_\phi(0, 0)$, (b) the internal energy E_N of modes (1, 1), (2, 1) and (3, 1), and (c) the instantaneous linear growth rate of modes (1, 1), (2, 1) and (3, 1).

References

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3) Kasuya, N. et al.: J. Phys. Soc. Jpn. **76** (2007) 044501.