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Multi-scale structures of electric current generated by collisionless trapped electron mode turbulence

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Non-inductive current is essential to the magnetic fusion experiments. It is economical to increase the proportion of the bootstrap current in the magnetic fusion devices. Non-inductive current changes the radial current density profile and affects the magnetohydrodynamic (MHD) instabilities. The turbulence induced electric current is a kind of intrinsic current which is caused by the turbulence induced electron momentum transport[1,2,3]. This current affects the MHD instabilities, which provides a way to study the turbulent effects on the MHD instabilities. The features of the collisionless trapped electron mode (CTEM) turbulence-induced current are identified by using the gyrokinetic code GEM[4,5].

The characteristics of the perturbed electron function corresponding to current generation have been analyzed. It is shown that the barely passing electrons play a crucial role in the current generation in determining the magnitude and the direction of current.

The weakly driven CTEM case ($R_0/L_{T_e}=5$) and the strongly driven CTEM case ($R_0/L_{T_e}=10$) are performed and compared to demonstrate the zonal flow effects on turbulence-induced current. For the weakly driven case, with the lower turbulence saturation level, the zonal flow has negligible effects on turbulence-induced current. The fine structures are dominant (a few ion Larmor radii) which is caused by the gradient of the turbulence intensity and the resonance between the turbulence and the fast moving electrons[6]. For the strongly driven case, with the higher turbulence saturation level, the zonal flow shearing rate (Ω_s) is $2-4$ times larger than the mode frequency (Ω). The zonal flow breaks up the turbulence eddies and provides an additional symmetry breaking mechanism which drives the current. Two characteristic radial scales of the current induced by CTEM are separated by the wavelet transformed method. One is the fine structure and the other is the mesoscale structure (tens of ion Larmor radii) which is related to the zonal flow shearing effects.

For the multi-n simulations of the strongly driven case, the low-n modes are dominant in the nonlinear stage. The turbulence-induced current density structure is determined by the synergistic effects of zonal flow shear (related to the mesoscale structure) and the symmetry breaking near rational mode surfaces (related to the fine scale structures). As shown in Fig.1, CTEM with the strongly driven parameters induced current density is about 50% as the bootstrap current density in magnitude near the rational mode surfaces.

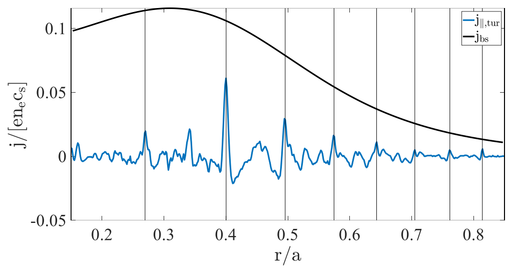

Figure 1. CTEM turbulence-induced current density profile (blue line) and the bootstrap current density profile (black line).

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