1-4. Theoretical Study

Collisionless long-time responses of the zonal-flow potential to the initial condition and turbulence source in helical systems having radial electric fields are derived theoretically. It is shown that, when the radial displacements of helical-ripple-trapped particles are reduced either by neoclassical optimization of the helical geometry lowering the radial drift or by strengthening the radial electric field to boost the poloidal rotation, enhanced zonal-flow responses are obtained.

Novel non-local interactions of microscopic turbulence via zonal flow are investigated. The radial correlation length of Zonal Flow (ZF) is longer than those for microscopic fluctuations, so that strong fluctuations at particular radius can suppress fluctuations at different radius, via induction of ZFs. This is called the seesaw mechanism via ZFs. The threshold of turbulence suppression is formulated as a global condition. The transient response is much faster than the process governed by diffusive processes.

In order to investigate the neoclassical and anomalous transport quickly, the effective helical ripple ε_{eff} and damped zonal flow response $|1\text{-}K_L|^2$ are estimated in L=2 heliotron with various shapes of outermost flux surface. The L=2 heliotron is characterized by three small parameters for the Fourier spectrum of the outermost flux surface, toroidicity δ_t, helicity δ_h, and a helical twisting parameter, δ_b. It is shown that both the effective helical ripple and damped zonal flow have minimum points as a function of the δ_b.

To understand the plasma response to the resonant magnetic perturbations (RMPs) in tokamaks, 3D MHD equilibrium calculations for realistic tokamaks were done using a 3D MHD equilibrium calculation without an assumption of perfectly nested flux surfaces in a priori. The stochasticiy is changed by the plasma resposne.

The equilibrium beta limit is studied using a 3D MHD equilibrium calculation without an assumption of perfectly nested flux surfaces in a priori. For high-beta equilibria, magnetic field lines in the peripheral region become stochastic due to the plasma response. If the stochastic region invades to the plasma core, the equilibrium force balance can not be kept. Thus, the pressure gradient is reduced in the region. This suggests an effective equilibrium beta limit.

Scenario development towards further extension of ion temperature (Ti) in LHD has been pursued. The utilization of the electron root might be a candidate through the simultaneous increase of Ti and electron temperature (Te), to further decrease of neoclassical (NC) heat diffusivity. The NC-ambipolar radial electric field (Er) calculations have revealed that the electron root realization becomes easier in deuterium plasmas than hydrogen plasmas through the enhanced reduction of ion particle flux with respect to Er in heavier ion species.

The electron-root Er also becomes larger for the same temperature conditions in deuterium plasmas, realizing the smaller NC transport.

Neoclassical transport code FORTEC-3D is applied to the transport analysis in high-*Ti* LHD experiment cases. We found that the discrepancy of ion-root *Er* between FORTEC-3D and conventional analysis like GSRAKE is larger as the ion temperature becomes higher. It suggests not only the finite-orbit-width (FOW) effect but also the ∇B- and curvature drifts of ions, both of which have been neglected in conventional neoclassical calculation, are effective for high-*Ti* LHD cases.

Recent LHD and DIII-D experiments show that the conventional modeling of edge plasma transport is not sufficient for expressing the transport phenomena in the ergodic region including magnetic islands with lower-collisionality. In order to estimate the transport coefficients, we develop a drift-kinetic equation solver and apply it to the edge disturbed by resonant magnetic perturbations under the assumption of neglecting electric field and neutrals. The results of the simulation will be reported in near future.

Another nonlinear MHD simulation has been executed in a heliotron-type configuration with a large pressure gradient to reveal the nonlinear dynamics of collapse phenomena of plasma. The simulation result reproduces the basic characteristics of the experimental observation on the so-called core density collapse (CDC) event in LHD with a large pressure gradient of the IDB. The spatio-temporal development of the core pressure structure is revealed in detail.

The nonlinear evolution of the non-resonant pressure driven mode was numerically studied by utilizing a multi-scale simulation scheme based on the reduced MHD equations. The beta value is increased by adding a peaked pressure increment continuously. When the pressure gradient at the magnetic axis becomes sufficiently large, the non-resonant mode is excited and saturated. This result corresponds to the sawtooth-like oscillation which was observed in the LHD experiment.

We have developed a multi-scale MHD simulation scheme to understand consistently the dynamics in the increase phase of beta. In this study, we have improved the previous version of the scheme so that the continuous heating effect and the dissipation of the background pressure are incorporated. We applied this scheme to the low-beta LHD configuration. The result indicates again a stable path to a high beta regime, which has been achieved in the experiments.

Interaction between resistive interchange mode and static magnetic islands generated by an external perturbed field in a straight LHD configuration is numerically studied. The interchange mode can change the width and the phase of the islands. Such change can be explained by the fact that the poloidal magnetic flux of the islands is approximated with the sum of the externally imposed flux and the perturbed flux generated by the interchange mode without the static islands.

The turbulent structural formation mechanism and their selection rule have been studied by numerical simulations of resistive drift wave turbulence in magnetized cylindrical plasmas. Selective formation of the zonal flow and streamer can be identified by changing the strength of the damping force of the zonal flow. It is found that the mediator mode plays an important role for sustaining the streamer in spite of the other possible candidates

The combination of the transport loss of the energy and radiative loss is analyzed in the case of the IDB/SDC plasmas using coupled one-dimensional transport equations in helical plasmas. In order to realize the stationary condition, the minimum and necessary electron heating power can be obtained. The critical density n_c shows the relation as the function of the minimum electron heating power P_{min}, $n_c \propto P_{min}^{0.614\pm0.001}$.

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