1-3. Theoretical Study

Theoretical and simulation studies, which have been done on the Large Helical Device (LHD) plasmas through the NIFS collaborative research programs in the Japanese fiscal year 2013, are reported in this section.

The LHD plasma with the background magnetic field changing, which corresponds to the magnetic axis swing experiment, is numerically analyzed with a new multi-scale simulation scheme to treat the time evolutions of the equilibrium and the perturbation in different time scales simultaneously. By performing the multi-scale simulations, the time evolutions with a partial collapse of the plasma pressure are obtained in the case with the background field changing while there is no excitations of instabilities in the case without the background field changing, as observed in the experiment.

Stability of high beta plasmas in LHD is investigated by full MHD simulations using MIPS (MHD Infrastructure for Plasma Simulation) code, in which effects of the chaotic magnetic field region are taken into account. In order to clarify the influence of the boundary condition on the MHD instability, the MIPS code is improved to treat free boundary problem using the pseudo-vacuum plasma model. The linear growth rate obtained by the free-boundary condition is shown to be about twice as large as one obtained by the fixed-boundary condition. Besides it is found that the position of the maximum amplitude of the eigen-mode structure shifts outward when the free-boundary condition is used.

Electromagnetic turbulence in finite-beta Large Helical Device (LHD) plasmas is studied by means of gyrokinetic simulations. The simulation results show common features to those found in gyrokinetic simulations of finite beta tokamaks such as the stabilization of ITG modes, the destabilization of KBMs, and weak zonal flows in KBM turbulence. The turbulent transport due to the ITG in LHD plasmas with the local beta value β = 0.2% is regulated by zonal flows, even in the presence of electromagnetic perturbations. The contribution of convective part to the energy flux is comparable with that of the turbulent diffusive heat flux part, because of the finite density gradient of the model configuration of LHD. For a small density gradient that is often observed in LHD, the contribution of the convective part can be different from the results obtained here. It is also found that magnetic perturbations have small pinch effects on the energy and the particle fluxes. In addition, saturation processes of KBM turbulence in LHD is elucidated by the nonlinear entropy transfer analysis.

Studies on peripheral plasmas in Large Helical Device (LHD) with ergodic and divertor regions are done by using a three-dimensional fluid code to simulate parallel and perpendicular transport of plasma and neutral particles. A series of simulations for the open and closed divertor configuration are carried out and a good agreement between simulation and experimental results are obtained on scaling of neutral gas pressure to the electron density for a fixed heating power.

High-energetic particle confinement in a geodesic winding helical reactor with D-shaped magnetic surface is studied. It is shown from particle simulations that the geodesic winding D-shaped helical magnetic field configuration can actively control the confinement and exhaust of alpha particles.

An integrated transport analysis suite, named TASK3D-a (analysis version), has been developed in order to extend physics understandings for the energy confinement and increase the predictability of plasma performances in present experiments and future reactors. It has an LHD experiment data interface part, which has a direct link to a so called LHD Kaiseki (analysis in Japanese) Data Serve and TSMAP (real-time coordinate mapping system). Through extensive TASK3D-a applications, the ion and electron heat diffusivityies are obtained as functions of temperature ratio, T_e/T_i, at a specific radius, r_{eff}/a_{99}~0.4, based on dynamic transport analyses. Generally, data for T_e/T_i <1 correspond to high-Ti plasmas, and those for T_e/T_i>1 to medium-to-high density plasmas. The tendency is recognized that the normalized ion (electron) heat diffusivity decreases (increases) as T_e/T_i is decreased.

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