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 2012, are reported in this section.

A partial collapse observed in the magnetic axis swing experiments in the Large Helical Device (LHD) is analyzed with a magnetohydrodynamics (MHD) numerical simulation. The situation obtained in the experiments is reproduced in this simulation where the collapse occurs in the case with the change of the field and the plasma is stable in the case without the change of the field. The collapse results from the fact that an infernal-like mode is destabilized. The destabilization is caused by the change of the background field through the enhancement of the magnetic hill.

MHD stability analyses are performed for high β LHD plasmas with the central beta values β_0 =7.4%, 9.4%, and 11%. The MHD equilibria are constructed by the HINT2 code while the linear and nonlinear MHD simulations of the resisitive ballooning modes are done by using the MIPS code (MHD Infrastructure for Plasma Simulation). It is found that, as β increases, the linear growth rate and the saturation level of the pressure driven modes are reduced.

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. The TASK3D-a ("a01" as the first version) consists of 4 parts, LHD Data interface, 3D equilibrium, heating, and energy/momentum balance analysis. The TASK3D-a can analyze the temporal behavior of energy confinement property in transient plasmas and identify when confinement improvement occurs. Thus, analyses on energy confinement of LHD plasmas can be significantly accelerated.

The global drift kinetic simulation code FORTEC-3D can treat the finite orbit width effect, which is caused by the radial drift of plasma particles and becomes more influential in higher temperature plasmas. The electron thermal diffusivity and the formation process of the ambipolar radial electric field are investigated by the FORTEC-3D simulations for the Core Electron-Root Confinement (CERC) plasma that is characterized by the high electron temperature (Te) and the steep Te gradient of the electron internal transport barrier (eITB). In order to improve the two-weight δf Monte Carlo method, which leads to a large numerical noise in a longer time simulation due to the so-called weight spreading, an improved control-variate technique is applied to a new local neoclassical transport code based on FORTEC-3D. The new technique is effective for reducing the numerical noise occurring in the δf Monte Carlo simulation.

Resonant magnetic perturbation (RMP) fields have a stabilizing effect on the radiating edge plasma, realizing stable sustainment of radiative divertor operation in the LHD. Three-dimensional structures of radiation distribution in the LHD with and without RMP fields are analysed using the edge transport code EMC3-EIRENE. It is found that, with RMP fields, the peaked radiation region moves to the plasma bottom, where the X-point of m=1/n=1 island is located. The results suggest that selective cooling occurs around the X-point. Comparisons of the radiation structures between the experiments and the simulations are made in detail. Furthermore, in order to realize edge/divertor simulation in closed divertor configuration, the calculation mesh of EMC3-EIRENE is extended from the plasma edge to the divertor legs and the vacuum regions.

Confinement of high-energy particles produced by NBI heating is one of important subjects to realize the helical reactor. A Monte Carlo code MORH is developed, which calculates the distribution function after the relaxation of high-energy particles. In the MORH code, the particle loss boundary is set at the vacuum vessel wall so that effects of reentering particles on the distribution function can be taken into account. The MORH code is improved so as to accurately treat particle orbits in the presence of the plasma current. The improved code is applied to low B and high β LHD plasmas, and effects of the plasma current on high-energy particles produced by NBI is investigated.

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