§4. Development of Integrated Simulation Code for Helical Plasma Experiments

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An integrated simulation code for non-axisymmetric plasmas is developed to draw up new experimental plans including those in a new device and to do experimental data analysis from the view point of integrated physics. The integrated simulation system to be developed has a modular structure which consists of modules for calculating MHD equilibrium/stability, transport and heating. If we need to perform an integrated simulation during the entire plasma duration, a transport module is to be a core module. In our project, an integrated tokamak transport code, TASK[1] is extended for non-axisymmetric configurations (TASK3D) and used as a transport module.

Major differences between transport simulations for a tokamak plasma with two dimensional MHD equilibrium and those for an helical plasma with three dimensional MHD equilibrium are the neoclassical ripple transport and its related time evolution of radial electric field. Moreover, an equation describing time evolution of toroidal current profiles is also different from that for tokamaks because of the non-axisymmetry of the MHD equilibrium.

In this fiscal year, we have developed a new module, TASK/ER, which calculates the time evolution of the radial electric field profile. When we determine the radial electric field in a helical plasma, the calculation of the neoclassical ripple transport is necessary. At present, Shaing's formula and DCOM/NNW (Monte-Carlo code + neural network code) is available for this calculation in ER. Figure 1 shows the example of the transport simulation performed by the combination of TR transport module, ER module and DCOM/NNW module for LHD plasma. In this simulation, time evolution of the electron and ion temperature profiles and the radial electric field profile are calculated using experimental data for the density profile and the heating power profile.

Although MHD equilibria can exist for zero net current in helical plasmas, finite net toroidal currents have been observed in many actual experiments even when Ohmic current is not driven actively. It is considered that the non-inductive current, such as bootstrap and beam driven currents are the main component of the net plasma current. However, change of the plasma current due to the non-inductive current induces inverse toroidal electric field when the plasma resistivity is small and the current penetration time is long. In other word, the inversely induced current is driven so as to suppress the change of the plasma current. Since the rotational transform profile, which has important roles on the MHD stability and confinement, is sensitive to the net plasma current, it is indispensable to clarify the effect of inductive component of the plasma current qualitatively. The TASK/EI module is available to calculate the time evolution of the plasma current in such a case. Figure 2 shows the example of the rotational transform evolution obtained by TASK/EI for an SDC plasma in LHD.

We have also developed FIT3D and WM modules to analyse the NBI heating and ICRF heating (see Fig.3, for example), respectively. We will perform integrated transport simulations by combining the modules we have developed, and will compare the result with the experimental one in the next fiscal year.

1) M. Sato, et al., "Development of hierarchy-integrated simulation code for toroidal helical plasmas, TASK/3D", to be appeared in Plasma Fusion Research.
2) Yuji Nakamura, et al., "Time evolution of the rotational transform profile in current-carrying LHD plasmas", to be appeared in Plasma Fusion Research.

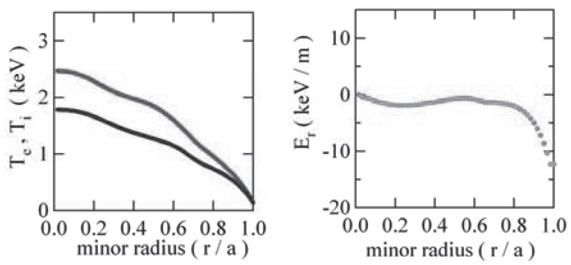

Fig.1 Steady state profiles of the electron temperature, the ion temperature, and the radial electric field obtained by the transport simulation of LHD.

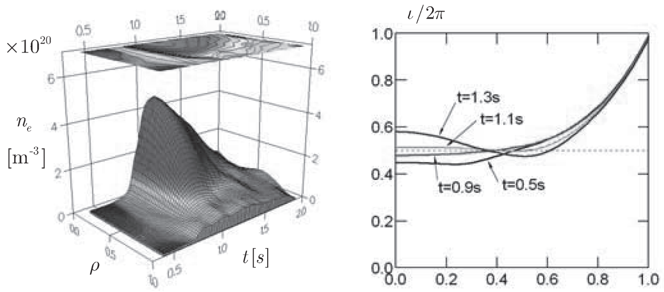

Fig.2 Time evolutions of the experimentally observed density profile (left) and the rotational transform profiles (right) obtained from the simulation for an SDC plasma in LHD.

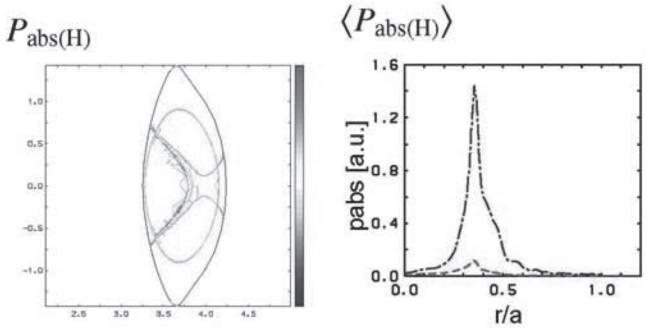

Fig.3 Wave analysis and absorpsition power for ICRF heating in an LHD plasma by TASK/WM.