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

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Recent development of plasma diagnostics technique combined with the progress of computers and numerical code for non-axisymmetric plasmas such as helical plasmas enable us to do detailed theoretical analyses of individual experimental observation. We can obtain detailed and fine scale experimental data, and theoretical analysis for realistic configuration becomes possible. This background motivates us to develop an integrated simulation code for non-axisymmetric plasmas 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. Each module can be selected in accordance with a user's request and can be combined with other modules. In order to maintain the independence of each module, which is an independent and complete program, sequences of the integrated simulation are controlled by a shell or script (perl or ruby, for example). Since some modules are suitable for running on the vector machine and others are on the PC cluster, we are going to develop a module-by-module distributed computing system through the network.

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], which is a core code for BPSI (Burning Plasma Simulation Initiative; research collaboration among universities, NIFS and JAERI in Japan) activity, will be extended for non-axisymmetric configurations and used as a transport module.

Though the most transport simulations done for helical plasmas have neglected the net toroidal current, finite net plasma current has been observed in actual experiments. It is considered that non-inductive currents such as bootstrap currents or beam driven currents are included in it. However, it is difficult to estimate fraction of these components accurately because plasmas are not stationary in many cases. So, as a first step of the extension of the TASK, time evolution of the plasma net current, which is consistent with the three-dimensional MHD equilibrium, is solved for LHD plasmas by using time evolution of density and temperature profiles obtained by the experiment and by taking into account of the bootstrap current and the beam-driven current.

In order to calculate the bootstrap current, we have developed the BSC code, which is suitable for the usage as a module, by improving SPBSC code[2]. This code uses a connection formula of asymptotic solutions for bootstrap currents of non-axisymmetric plasmas in Pfirsch-Schülter, plateau, and low collisionality regimes. Ohkawa current driven by the NBI is calculated by the FIT code[3].

In order to estimate the inductive currents, evolution of the rotational transform by the plasma resistivity in a non-axisymmetric plasma is derived as[4]

$$\frac{\partial \iota}{\partial t} = \frac{1}{4\rho {\Phi_{T_a}}^2}\left[\frac{\partial}{\partial \rho}\left\{\eta_\parallel \frac{dV}{d\rho}\frac{\langle B^2\rangle}{\mu_0 \rho^2}\frac{\partial}{\partial \rho}\left[\rho\left(S_{11}\iota + S_{12}\right)\right]\right\} + \frac{\partial}{\partial \rho}\left\{\eta_\parallel \frac{dV}{d\rho}\frac{1}{\rho}\frac{dp}{d\rho}\left(S_{11}\iota + S_{12}\right) - \eta_\parallel \frac{dV}{d\rho}\frac{1}{\rho}\langle \boldsymbol{j}_s \cdot \boldsymbol{B}\rangle\right\}\right]$$

where S_{11} and S_{12} are susceptance matrix elements[5] calculated by the metric tensors of three dimensional equilibrium, and $\langle \boldsymbol{j}_s \cdot \boldsymbol{B}\rangle$ represents the non-inductive current. A numerical simulation is done for an LHD neutral beam heated plasma (Fig.1). In this simulation, non-inductive current $\langle \boldsymbol{j}_s \cdot \boldsymbol{B}\rangle$ (Ohkawa current and bootstrap current in this case) is calculated by BSC/FIT code. It is shown that the abrupt increase of plasma current by Ohkawa current is suppressed by the inductive component of the plasma current. Because of the finite resistivity, total net current gets close to the non-inductive current with time.

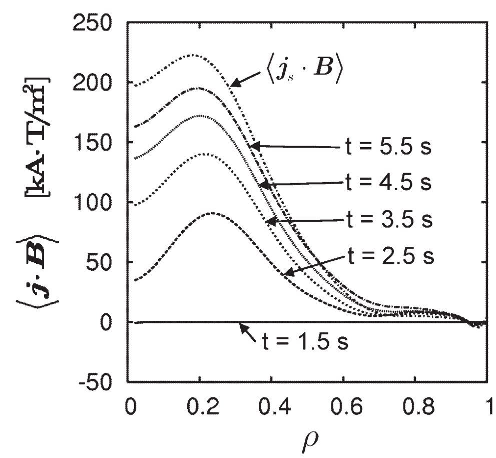

Fig. 1. Time evolution of net plasma current profile in an LHD NB heated plasma.

References

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