§18. Implementation of NBI Heating Module FIT3D to Hierarchy-integrated Simulation Code TASK3D

Sato, M., Murakami, S. (Kyoto Univ.),
Fukuyama, A. (Kyoto Univ.), Nakamura, Y. (Kyoto Univ.),
Watanabe, K.Y., Toda, S., Yokoyama, M.,
Funaba, H., Yamada, H., Nakajima, N.

An integrated modeling code for three-dimensional configurations, TASK3D, is being developed on the basis of an integrated modeling code for tokamak plasmas, TASK(Transport Analyzing System for tokamaK)[1]. In order to extend the TASK to the TASK3D, modules for rotational transform module (EI module) and radial electric field module (ER module) were developed and implemented[2,3]. In this study, the further development of the TASK3D, implementation of the NBI (Neutral beam injection) heating module (FIT3D module), is reported[4].

The FIT3D has been developed based on three simulation code[5]: HFREYA, MCNBI and FIT, where HFREYA evaluates beam ion birth points using Monte-Carlo method and MCNBI calculates radial redistribution of beam ions due to prompt orbit effects. Then, heating profiles are obtained by FIT code solving the Fokker-Planck equation. In order to check the applicability of the FIT3D module, test simulation has been performed by using the combination of VMEC module, TR module, ER module and FIT3D module. The TR module is a one-dimensional diffusive transport module for solving particle transport and heat transport equations. The heating power calculated by the FIT3D module is added to the energy source term in the heat transport equation. In the ER module, the radial electric field E_r is determined from the ambipolar condition $\Gamma_e = \Gamma_i$, where Γ_e and Γ_i are electron and ion neoclassical particle flux, respectively. For the evaluation of the neoclassical transport flux, DCOM/NNW[6] is used here. By the TR module, the electron and ion temperatures are updated and then their profiles are used for input parameter of the FIT3D module. Then, the heating power is recalculated for new temperature profiles. The procedure are repeated and the steady temperature profile is obtained.

In the simulation, the initial temperature profiles of electron and ion are chosen as $T=0.09(1-\rho^2)+0.01$ [keV]. The density profile is chosen as $n = 1.99(1-\rho^8)+0.01$ [$10^{19}/m^3$]. Anomalous transport coefficient is assumed as $\chi^{an}=2/(1-0.85\rho^2)$ [m^2/s]. The profiles of the density and the anomalous transport coefficient are fixed with time in this simulation. The magnetic field strength is assumed to be B=0.452 [T]. In the FIT3D module, the three tangential NBI in LHD are considered. The injection beam ion energy E_b and beam power P_b are (E_b, P_b) = (170 keV, 3.45 MW), (150 keV, 2.75 MW), (148 keV, 2.75 MW), respectively. Figure 1 shows time evolution of the electron and ion temperature at the plasma center. After about t=0.06 [s], the profiles reaches to the steady state. For the steady state, the profiles of the heating power is shown in Fig.2.

From the test simulation, the applicability of the FIT3D module and the linkage of essential modules for analysis of the transport phenomena in LHD have been confirmed. The evaluation of the energy confinement time for various anomalous transport models is a future work.

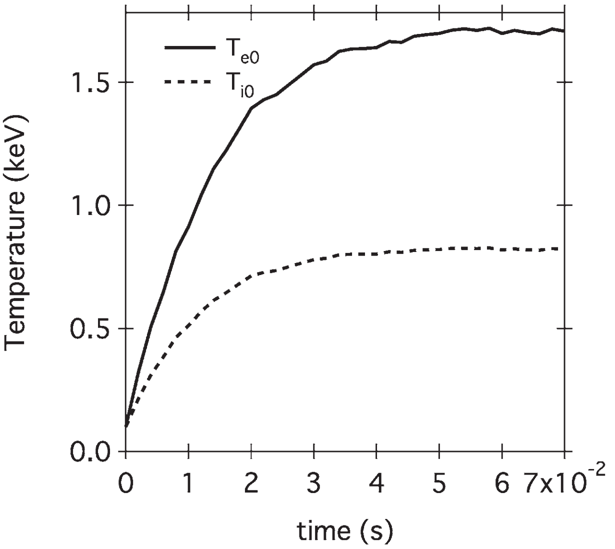

Fig. 1. Time evolution of electron (T_{e0}) and ion (T_{i0}) temperature at the plasma center.

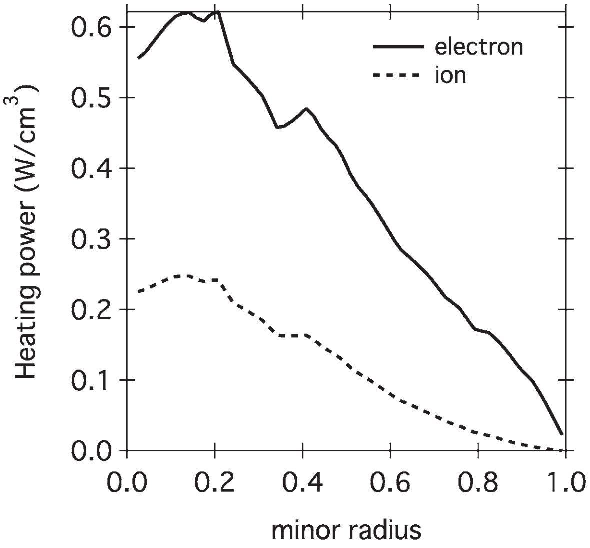

Fig. 2. Radial profiles of electron and ion heating power at t = 0.07[s].

1) A. Fukuyama *et al.*, Proc. of 20th IAEA Fusion Energy Conf. (Villamoura, Portugal, 2004)IAEA-CSP-25/CD/TH/P2-3.
2) Y.Nakamura *et al.*, Proc. of of 21st IAEA Fusion Energy Conf. (Chengdu, China, 2006) IAEA-CN-149/TH/P7-1.
3) M.Sato *et al.*, Plasma Fusion Res. **3** (2008) S1063.
4) M. Sato *et al.*, Proc. of 18th Int. Toki Conf. (2008) P1-05.
5) S. Murakami *et al.*, Trans. Fusion Technol. **27** (1995) 259.
6) A.Wakasa *et al.*, Jpn. J. Appl. Phys., **46** (2007) 1157.