§7. Confinement Analysis Code Development and Magnetic Configuration Control

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Among fusion confinement configurations, the tokamak concept seems to be best at present from the view-point of the plasma confinement and the simple axi-symmetric system. However, in this system the pulsed operation and current disruption events are serious problems to be solved. Here, we proposed a new magnetic configuration combined with tokamak and helical systems to avoid disruptions, and developing toroidal transport linkage code TOTAL (Toroidal Transport Analysis Linkage) with both tokamak and helical versions.

In the analysis using the TOTAL-H(Helical version), magnetic field tracing code HSD is used to define vacuum magnetic surfaces, and the DESCUR code is used for Fourier mode analysis of the vacuum last closed surface. The finite-beta three-dimensional equilibrium was solved by the free-boundary VMEC code, and the effects of current-free or flux-conserving high-beta configuration were evaluated fitted to the various LHD experimental data. A 1-dimensional transport HTRANS with neoclassical loss determined by ambipolar radial electric field as well as anomalous transport.

The time-dependent simulation of neutral-beam-heated LHD plasmas has been carried out using the TOTAL-H code focusing on the time evolutions of beam energy and kinetic energy. The neutral beam deposition is calculated by the Monte Carlo code HFREYA, and the slowing down process was calculated by the Fast Ion Fokker-Plank code FIFPC.

The simulation results and typical experimental plasma energy data observed by diamagnetic coil measurement are shown in Fig. 1. In this figure, W_{total} is the summation of the simulated kinetic plasma energy, W_{plasma} = 3nk(Te + Ti)/2, and the beam energy, W_{beam}. In order to compare W_{exp} and W_{total} , we should define $W_{total} = W_{plasma} + fW_{beam}$, where f ~ 1/5 - 1/3. The profiles of W_{exp} and W_{total} roughly agree with each other. The simulated time evolution of total energy including beam energy roughly agrees with the time evolution of the experimentally measured energy. The temporal change in the beam velocity distribution is also clarified [1].

In the TOTAL-T(Tokamak version) the 2-D free-boundary APOLLO equilibrium code is used and the 1-D transport code was solved. For the prediction of the ITER plasmas, the effect of the neoclassical tearing mode (NTM) on the plasma confinement has been calculated related to minor disruptions. The time-evolution analysis of the NTM magnetic island has been calcurated in the TOTAL code using the modified Rutherford equation for a ITER normal shear plasma. The anomalous transport model used here is GLF23 model.

In an ITER plasma the NTM magnetic islands are saturated around ten seconds after introducing the seed island. Figure 2 shows the electron temperature profile and the q profile when the magnetic island is saturated. The 3/2 mode island (q=1.5) exists at r/a=0.67, and the 2/1 mode island (q=2) exists at r/a=0.84. We assumed the transport coefficient is quite large inside the magnetic island. The saturated magnetic island widths are w/a~0.048 at 3/2 mode and w/a~0.21 at 2/1 mode, and the reduction in fusion power output by NTM is 27% at the 3/2 mode, and 82% at the 2/1 mode. The stabilization effect of the electron cyclotron current drive (ECCD) with EC is also clarified. The threshold ECCD power for the full stabilization is ~10[MW] against the 3/2 mode, and ~23[MW] against the 2/1 mode.

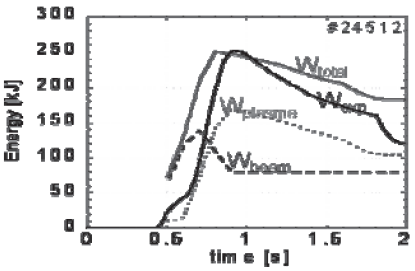

Fig. 1. Time evolution of experimental and simulated beam/plasma energy in LHD. [1]

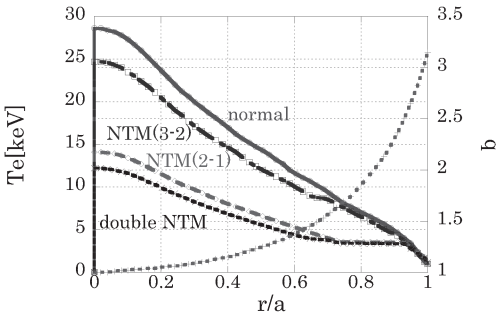

Fig.2. Electron temperature and safety factor q profile without and with 3/2 and 2/1 neoclassical tearing modes in ITER.[3]

1) Ohnishi, T., Yamazaki, K., Funaba, H., Arimoto, H., Shoji, T., "Time-Dependent NBI-Heating Simulation of LHD Plasmas with TOTAL (Toroidal Transport Analysis Linkage) Code", Proceedings of ITC/ISHW2007 (15-19 October 2007, Toki, Japan)
2) Takahashi, Y., Yamazaki, K., Garcia, J., Arimoto, H., Shoji, T., "Tokamak Plasma Transport Simulation in the Presence of Neoclassical Tearing Modes" Proceedings of ITC/ISHW2007 (15-19 October 2007, Toki, Japan)
3) Takahashi, Y., Yamazaki, K., Arimoto, H., Shoji, T.,"H-Mode Plasma Transport Simulation in ITER with Effect of Neoclassical Tearing Mode", Proc. 11th IAEA Technical Meeting on H-mode Physics and Transport Barriers (26-28 September 2007, Tsukuba, Japan)