§16. Confinement Optimization Study of an Advanced Helical System for a Compact, High-beta, Steady-state Reactor

Sano, F. (Institute of Advanced Energy, Kyoto Univ.)

The collaboration research between the Helitoron J group and other experimental groups such as the LHD and the CHS groups has been continued to understand machine-independent torus plasma confinement physics through the systematic study using the data obtained in this collaboration for five years.

The five schemes for the collaboration research have been selected; (1) study of core plasma transport, (2) study of edge plasma transport, (3) plasma heating and toroidal current control, (4) study of MHD equilibrium, stability and divertor, (5) physical design of the optimization of helical field. Each group joined the plasma experiment and data analysis including the usage of fast internet for data exchange and analysis. The experiments of the particle control concerning categories (1) and (2), electron cyclotron current drive (ECCD) study concerning category (3), and study of GAE mode concerning category (4) are reported below.

Study of New Particle Control Method[1)]

Plasma density and neutral density in the plasma outer region are controlled using gas-puffing ordinarily. For seeking a more effective particle supply method, super-sonic molecular beam injection (SMBI) is applied. The plasma stored energy of 4.5 kJ ($\bar{n}_e = 4\times10^{19}\,\mathrm{m}^{-3}$) was achieved for ECH (~0.35 MW) plus NBI heating (~0.6 MW) plasma by using SMBI. This value is almost 1.5 times of that in gas-puffing. The Hα signal near the SMBI port indicates the injected gas behavior. It increases with the SMBI gas, and then the electron density begins to increases. However, the Hα signal far from the SMBI port once decreases, and then it increases gradually. This behavior is similar to the beginning of H-mode. SMBI method enhanced the operation region of density and stored energy.

Study of Electron Cyclotron Current Drive (ECCD)[2)]

The ECH injection system was changed in order to focus the ECH injection beam and control the refractive index in the parallel direction ($N_{//}$). The variable region of $N_{//}$ is from -0.05 to 0.6. The beam radius at the magnetic axis is 0.03 m. The mode of injection beam is mostly X-mode and adjusted to the second harmonic heating. In the condition of $N_{//} = 0.38$, injection power=0.27 MW, $\bar{n}_e = 0.5\times10^{19}\,\mathrm{m}^{-3}$ and STD configuration, the resonance location is changed by the magnetic field strength. The toroidal current decreased from ~2 kA to ~0.2 kA for the location from ω_0/ω=0.478 to 0.517. Changing injection angle to be $N_{//} = 0$, the bootstrap current is observed. The absorption location dependence is almost the same as the previous case. Then, it is considered that the EC current is very small in the low field side heating. The current increases monotonically as the resonance location moves to the high field side. The driven current direction coincides with that from the Firsch-Boozer effect. The dependence of the toroidal current on $N_{//}$ is also investigated. The absorption location of ω_0/ω=0.478 is selected. The current and ECE signal are largest near $N_{//} = 0.3$. It is supposed that this ECE signal is caused by the fast electrons, which affect the current drive efficiency.

Fast ion transport by GAE in NBI heating[3)]

In the configuration of good confinement for fast ions, large GAE bust is observed. The fast ion transport is investigated by using a directional probe and a magnetic probe. This directional probe can observe the ion particle flux from both co-direction and counter direction. The experiment is performed under the condition that the configuration is in the normalized rotational transform of 0.54, NBI is co-direction, $v_{b//}/v_A$ considering carbon impurity is about 0.5. GAE of m/n=2/1 is observed using the magnetic probe just after NB injection. GAE burst appears when the line-averaged electron density attains $1.5\times10^{19}\,\mathrm{m}^{-3}$. The frequency changes from 70 kHz to 40 kHz as the increase of the density from $0.4\times10^{19}\,\mathrm{m}^{-3}$ to $1.6\times10^{19}\,\mathrm{m}^{-3}$. This mode transmits in the direction of ion diamagnetic drift. The ion saturation current measured by the directional probe is mainly caused by the fast ions in this condition. Signals of the directional probe are synchronized with the GAE burst and have high coherence with the magnetic probe signal. The flux in the co-direction is almost proportional to the magnetic probe signal; therefore, it is considered that co-flux is pumped out by the GAE burst.

[1] T. Mizuuchi, et al, “Study of Improved Confinement Modes in Heliotron J” Proc. 17th International Stellarator/Heliotron Workshop (2009), I-24.

[2] K. Nagasaki, et al., “ECCD Experiments using Upgraded Launching System in Heliotron J”, *ibid.*, PO1-19.

[3] S. Kobayashi, et al., “Energetic Particle Transport in NBI plasmas of Heliotron J”, *ibid.*, I-31.