§15. A Study on the Confinement Optimization and Stability Control of an Advanced Helical System

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The main purpose of the bidirectional collaboration research of the Helitoron J group with NIFS is to proceed the allotted subject, "A study on the confinement optimization and stability control of an advanced helical system" in the 2^{nd} mid-term plan of MEXT on the basis of the former subject, "Confinement optimization study of an advanced helical system for a compact, high-beta, steady-state reactor". The steady progress for these subjects has been done in Heliotron J experiment. The collaboration research activity between the Helitoron J group and other experimental groups such as the LHD group, or other university groups must be extended to understand machine-independent torus plasma confinement physics through the systematic study.

The five schemes for the collaboration research have been selected; (1) study of confinement improvement and related plasma structural formation using field configuration control, (2) study of instability control using field configuration control, (3) study of toroidal current control, (4) study of fuelling control and heat/particle removal, (5) physical and mechanical design study of plasma fluctuation diagnostic devices such as a beam emission spectroscopy (BES) system. Each group joined the plasma experiment and data analysis including the usage of fast internet for data exchange and analysis. Electron cyclotron current drive study concerning category (3), fuelling method study concerning category (4), and study of plasma startup by the NBI concerning category (1) are reported below.

Study of Electron Cyclotron Current Drive (ECCD)[1)]

The effect of the magnetic field ripple on the ECCD, and the zero toroidal current by suppression of BS current have been demonstrated in Heliotron J experiment. The dependence of the 70-GHz second harmonic ECCD on $N_{//}$ is investigated by changing the injection angle of the focused EC Gaussian beam. EC current is proved to be controllable by changing injection angle. The maximum current is driven near $N_{//} = 0.4$. When the ECH wave is absorbed at the top of the magnetic field strength, the toroidal current flows in the direction due to the Fisch-Boozer effect. On the contrary, when the EC wave is absorbed at the bottom of the magnetic field strength, the current hardly flows. The ECE signal becomes stronger as the EC current increases. The high energy electrons affect ECCD from the consideration of the ECE signals with the optical thickness. The calculated results using a ray-tracing code, TRAVIS for the dependence of the EC current on $N_{//}$, magnetic field strength and configuration agree with the experimental results.

Study of Particle Control Method for Confinement Improvement[2)]

The further extension of the attainable parameter regions and improvement of confinement is one of objectives of this campaign after the success of the extension of the plasma parameter region using a super-sonic molecular beam injection (SMBI) in the last campaign. The molecular hydrogen beam speed by the SMBI is estimated to be 1-1.6 km/s by TOF. The effectiveness of the SMBI is supposed to be due to directivity of injected particles since the speed of the beam is not so fast compared with that of hydrogen at room temperature. Plasma response to SMBI is investigated using a shutter in front of the SMBI nozzle in order to estimate the effect of the directivity of the fuelling. The density and stored energy without the shutter is increased more and the saturated points are higher than those in shutter-closed case. The slope of the density profile at the plasma edge is steeper. It is concluded that the efficiency of fuelling is improved by focusing the injected particles.

Plasma Startup Using Neutral Beam Injection (NBI) Assisted by 2.45-GHz Microwaves[3)]

Neutral Beam Injection (NBI) plasmas have been initiated with the assistance of 5-kW, 2.45-GHz microwaves in Heliotron J. Plasmas with a line averaged electron density of over 1×10^{19} m^{-3} are generated with 1-MW NBI using a magnetic field between 0.63 and 1.25 T within 20 ms after turning NBI on. This technique does not require the electron cyclotron layers for the plasma startup, then, the operational space for the magnetic field strength can be extended. Electron cyclotron emission measured with a radiometer reveals that the 2.45-GHz microwaves play an important role for the startup.

[1] K. Nagasaki, et al., "Experimental Study of Second Harmonic ECCD in Heliotron J", 23rd IAEA Conference, Daejeon, Korea (2010) EXW/P7-19.

[2] T. Mizuuchi, et al, "Fueling Control for Improving Plasma Performance in Heliotron J", 23rd IAEA Conference, Daejeon, Korea (2010) EXC/P8-11.

[3] S. Kobayashi, "NBI experiments in Heliotron J", 37th EPS Conference on Plasma Physics, Dublin, Ireland (2010) P1.1053.