§18. 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 Heliotron J group with NIFS is to pursue the allotted subject, "A study on the confinement optimization and stability control of an advanced helical system" in the 2nd mid-term plan of LHD in NIFS. From this FY year, two new subjects for the research center linkage project, (a) "Studies of ECH/EBW heating and current drive" and (b) "Studies of heat/particle control (edge plasma control)" are promoted to seek the optimization of an advanced helical system.

The six schemes for the collaboration research have been selected; (1) confinement improvement and related plasma structural formation using field configuration control, (2) instability control using field configuration control, (3) ECH/EBW heating mechanism, (4) toroidal current control, (5) fuelling control and heat/particle removal, (6) physical and engineering 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. Fast ion confinement study concerning category (1), particle confinement study using density modulation method concerning category (1), and study of BES concerning category (6) are reported below.

Magnetic Field Configuration Dependence on Fast Ion Confinement

Fast ion velocity distribution in the low density region (0.4×10^{19} m^{-3}) has been investigated using fast minority protons generated by ICRF minority heating (D majority) with special emphasis on the effect of the toroidal ripple of magnetic field strength (bumpiness) and heating position. The wide range observation (about 25% in the poloidal cross section of fast ions is performed by changing the line of sight of the charge exchange neutral particle energy analyzer (CX-NPA) in two directions for three bumpiness's. For the quantitative comparison of the fast ion tail, the effective temperature of fast minority ions is estimated from the energy spectrum in the range of 1 keV to 7 keV. The better performance of the high bumpiness is confirmed in this vertical angle scan of the CX-NPA at several horizontal angles. The tail temperature is largest in the high bumpiness case and the difference of the energy spectra in the vertical scan within 0.4 in the normalized minor radius is very small for the on-axis heating condition.

Study of Particle Diffusion Using Density Modulation

An AM reflectometer has been installed for the density profile measurement. The frequency of the reflectometer is from 33 GHz to 56 GHz and the sweeping frequency is 1 kHz in profile measurement. The flat or hollow density profile is measured in 70 GHz-ECH plasmas using X mode for wave transmission. By modulating density using gas puff control, particle diffusion coefficient is evaluated. The density fluctuation amplitude is kept constant during plasma duration time. The base plasma density is 0.6×10^{19} m^{-3} or 0.9×10^{19} m^{-3}. The density modulation frequency is 50 Hz and its amplitude is 0.1×10^{19} m^{-3}. Within the radius $r/a<0.6$, the assumed constant diffusion coefficient $D=D_{core}$ and the convection velocity $V=(r/a) \cdot V_{core}$ are D_{core} =2.3 m^2/s and V_{core} = 2.3 m/s for the higher density case and D_{core} = 5.2 m^2/s and V_{core} = 59 m/s for the lower density case. The larger convection velocity in the lower density case is considered due to density clumping phenomenon in ECH plasma.

Fluctuation Measurement by Using Beam Emission Spectroscopy (BES)

The BES system using NBI heating beam was developed for the density fluctuation measurement in Heliotron J. The spatial resolution of about 0.06 in normalized radius can be attained by setting the line of sight of the BES parallel to the magnetic axis in Heliotron J field configuration where the beam axis and plasma magnetic axis is crossed. The lines of sight of the BES consist of 16 optical fibers, which cover the area from 0.07 to 0.94 in normalized radius. The S/N ratio is greatly improved from the proto type device (FY2011) by 20 times. From this improvement, AC component is detectable as well as DC component. The radial profile of fluctuations of several tens kHz has been measured.

The publications from this collaborative research are listed below :

[1] H. Okada, et al., "Numerical Analysis of ICRF Minority Heating in Heliotron J", Plasma Fusion Res. **6** (2011) 2402063.
[2] K. Mukai, et al., "Electron Density Profile Behavior during SMBI Measured with AM Reflectometer in Heliotron J Plasma", Plasma Fusion Res, **6** (2011), 1402111.
[3] T. Mizuuchi, et al., "Comparison between supersonic molecular-beam injection and conventional gas-puffing for plasma performance in Heliotron J", J. Nucl. Mater. 415 (2011) 5443.
[4] K. Nagasaki, et al., "Influence of trapped electrons on ECCD in Heliotron J", Nucl. Fusion **51** (2011) 103035.