§13. Confinement Improvement Studies of Advanced Helical Systems

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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. The main purpose of this research is to promote experimental and theoretical studies based on the data of the improved confinement in Heliotron J and LHD/CHS for the optimization of helical confinement field aiming at the control of the transport in the helical plasmas.

The six schemes for the collaboration research have been selected; (1) study of transport and high energy particle confinement using advanced control of field components, (2) study of MHD equilibrium/stability using advanced control of field components, (3) experimental study of plasma current control using advanced control of field components, (4) study of ECH heating mechanism and improvement of its efficiency, (5) study of heat and particle pumping out control using advanced control of field components and (6) conceptual design and preparation of the measurement of the density and potential fluctuation. Each group joined the plasma experiment and data analysis including the usage of fast internet for data exchange and analysis.

Effects of magnetic file ripple on ECCD[1)]

Driving a non-inductive toroidal current in torus plasmas is considered to be a control method for generating high-performance plasma and sustaining long-duration plasma. Electron cyclotron current drive (ECCD) can be utilized to control toroidal current against a bootstrap current and suppress a local magnetic island in the confinement region. In Heliotron J, there is no inductive current, then the small amount of toroidal current is detectable in the various configurations. The driving mechanism of the toroidal current can be investigated on the order of several hundred amperes, easily. When the EC power absorption is positioned at the top of the magnetic field strength, the EC current flows in the direction of Fish-Boozer effect. On the contrary, when the power is absorbed at the bottom of the field ripple, the current flows in the direction of the Ohkawa effect. It is suggested that the amount of the trapped electrons affect the ECCD. In the power scan experiment, the driven current is nearly proportional to $P_{abs}T_e/n_e$. The normalized driven current efficiency $\zeta = e^3 n_e I_{EC} R/\varepsilon_0^{\,2} P_{EC} T_e$ is almost constant against injection power.

Fast ion confinement using ICRF minority heating[2)]

Fast ion velocity distribution is investigated using fast protons generated by ICRF minority heating in Heliotron J. The ICRF wave is injected into ECH plasmas. The line-averaged and ICRF injection power are 0.4 x 10^{19} m^{-3} and about 0.3 MW, respectively. The high energy component is observed near the pitch angle of 120 deg in the range of observation from 111 deg to 128 deg in the high bumpy case. The tail component extended to about 30 keV is observed only in the high bumpy case. The variation of energy spectra for the pitch angle is very small for the medium bumpy case. However, the amount of the high energy flux is largest near 120 deg as in the high bumpy case. In the low bumpy case, the pitch angle dependence is different from the other two cases. The slope of the energy spectra is gradually decreased from 127 deg to 108 deg.

Confinement of NBI plasmas[3)]

The higher stored energy of the counter injected NBI plasmas at $2\times10^{19}m^{-3}$ is observed in the high and medium bumpy configurations in comparison with the low bumpy configuration. The improvement factors of the energy confinement against ISS95 scaling are 1.8 and 1.7 for the high and medium bumpy cases, which are higher than 1.4 in the low bumpy case. The ion temperature measured by a charge-exchange energy analyzer is 240 eV in the high bumpy case at the absorption power of 200 kW. It was 200 eV and 180 eV for the medium and low bumpy cases. The bumpy component dependence on ion temperature is week. On the contrary, the ECE signal depends on absorption power and bumpy configuration. Therefore, the change of the stored energy is considered to be mainly due to the change of the electron temperature. The control of the bumpy component was found to be effective to control the global energy confinement of NBI plasmas.

1) K. Nagasaki, et al., "Effect of Magnetic Field Ripple on ECCD in Heliotron J", Proc. 22nd IAEA Fusion Energy Conference (2008) EX/P6-15.
2) H. Okada, et al., "Velocity Distribution of Fast Ions Generated by ICRF Heating in Heliotron J",Proc. 22nd IAEA Fusion Energy Conference (2008) EX/P6-28.
3) S. Kobayashi, et al., "Effect of Bumpy Magnetic Field on Energy Confinement in NBI Plasmas of Heliotron J", Proc. 22nd IAEA Fusion Energy Conference (2008) EX/P5-13.