§19. 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 2nd mid-term plan of NIFS. From FY 2011, two new subjects for the research center linkage project, (a) “Study of ECH/EBW heating and current drive” and (b) “Study of heat/particle control (edge plasma control)” are promoted to seek the optimization of 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 FIR interferometer 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.

Study of Energetic-Ion-Driven MHD Instabilities [1, 2]

Energetic alpha particles in a fusion reactor such as ITER would reasonably couples with MHD modes related to the Alfvén and sound waves in the slowing down process of alpha particle, and excite these MHD modes. The MHD mode could enhances the transport and/or induce the loss of alpha particles before their thermalization. This leads to reduction of net gain of fusion burn and significant damage of the first wall of a reactor. Therefore, energetic-ion-driven MHD instabilities such as Alfvén eigenmodes (AEs) have being studied in many tokamaks and helical devices for the purpose of clarification of the mechanism and minimization of the negative effect of AEs. In the standard configuration of Heliotron J, energetic-ion-driven MHD instability is observed. The frequencies of the m = 2/ n = 1 mode are in the range from 50 kHz to 95 kHz. This mode has dependence of $1/n_e^{1/2}$ as expected from theoretical analysis. The iota dependence of the shear Alfvén spectra is also investigated experimentally and theoretically. The two different GAE modes are observed; one of which increases with iota and the other decreases. This tendency is reproduced in the numerical simulations.

Study of Stabilization of Energetic-Ion-Driven MHD Mode by ECCD [3]

Instability suppression experiment is performed under the rotational transform control by using second harmonic ECCD to avoid deterioration of bulk confinement or energetic ion loss. Here, it is aimed that coherent MHD mode, EPM, with the high frequency larger than 30 kHz observed in NBI plasmas of Heliotron J should be suppressed by ECCD. Into balanced NBI plasmas of which density is 0.5×10^{19} m^{-3}, a focused EC wave is injected. The local heating can be realized since the diffraction effect is small in this low-density condition. By adjusting injection mirror, the beam is injected with $N_{//} = -0.3$. The toroidal current of 2kA in the co-direction is generated by ECCD. In this case, the EPM fluctuation with f = 80 kHz, m/n = 4/2 mode is reduced significantly. This fluctuation suppression is possibly caused by the magnetic shear generation from the EC driven current.

Study of Particle Fuelling Control [4]

The fuel control using a supersonic molecular-beam injection (SMBI) and high-intensity gas-puff (HIGP) is investigated aiming at optimization of gas-fuelling scenario. The SMBI is considered to be an effective method to control plasma density and its profile. The maximum stored energy after SMBI is about 20% higher than that after HIGP in the NBI-only sustained plasma experiment under the density of about 3×10^{19} m^{-3}. The electron and ion temperature of the plasma core region is higher and a peaked density profile is observed in the SMBI case. The amount of gas to obtain the same density increment is about 30-40% larger in HIGP compared to SMBI. The difference in density profile and neutral density could improve particle confinement.

[1] S. Yamamoto, et al., “Studies of Energetic-ion-driven MHD Instabilities in Helical Plasmas with Low Magnetic Shear”, 24th IAEA Fusion Energy Conference, San Diego, USA, 8-13 Oct. 2012, EX/5-2, [2] S. Ohshima, et al., “Edge Plasma Response to Beam-driven MHD Instability in Heliotron J”, 24th IAEA Fusion Energy Conference, San Diego, USA, 8-13 Oct. 2012, EX/P4-17, [3] T. Mizuuchi, et al., “Study of Fuelling Control for Confinement Experiments in Heliotron J”, 24th IAEA Fusion Energy Conference, San Diego, USA, 8-13 Oct. 2012, EX/P3-07, [4] K. Nagasaki, et al., “Stabilization of Energetic-Ion-Driven MHD Mode by ECCD in Heliotron J”, 24th IAEA Fusion Energy Conference, San Diego, USA, 8-13 Oct. 2012, EX/P8-10.