§23. 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 by controlling magnetic configuration and related plasma self-organization, (2) instability suppression by controlling magnetic configuration, (3) ECH/EBW heating physics, (4) toroidal current control, (5) fueling control and exhaust control of heat and particles, and (6) development of the FIR measurement system and so on. Each group joined the plasma experiment and data analysis including the usage of fast internet for data exchange and analysis. Study of high density plasma operation concerning category (1 and 5), stabilization of energetic-ion-driven MHD Mode by ECCD concerning category (3 and 4), and Edge plasma behavior affected by energetic particle driven instabilities concerning category (2) are reported below. The first topic is also one of the research center linkage project, (b) and the second is (a).

Study of high density plasma operation [1, 2]

To obtain high performance plasmas, the optimization study for gas-fuelling scenario has been carried out using supersonic molecular-beam injection (SMBI) and high-intensity gas-puff fuelling (HIGP) techniques in Heliotron J. The HIGP technique is effective to produce the plasmas with electron density higher than $1\times10^{20}m^{-3}$. In this experiment, the plasma is maintained by the balanced NBI heating with 1.1 MW in injection power and the plasma energy reaches about 6 kJ. After stopping HIGP, increases in the ion/electron temperatures and the co-rotating toroidal rotation are simultaneously observed in the peripheral (r/a>0.7) region. At that time, the reduction in the density fluctuation at the edge region is also observed in accordance with the sudden drop of the Hα/Dα intensity. This type of high-density condition is achieved only in the low (ε_t) configuration. The neutral simulation is carried out for investigating high elongation effect of this configuration.

Stabilization of energetic-ion-driven MHD Mode by ECCD [3]

ECCD experiments have been made for stabilization of energetic-ion-driven MHD modes in Heliotron J. Theoretical analysis shows that an EC current of a few kA driven in the central region modifies the rotational transform profile from a shearless flat one into a high-shear one. ECCD has been applied to ECH+NBI plasmas in which AEs are excited by energetic ions. The EPM, an energetic-ion-driven MHD mode, has been fully stabilized by centrally localized second harmonic 70-GHz X-mode ECCD. The configuration where $\iota/2\pi$ is near 0.5 is selected to observe such mode. In the magnetic configuration of $\iota/2\pi$ = 0.512 and 0.525, the EPM of 60-90 kHz is stabilized by the counter-ECCD which forms a positive magnetic shear. Since the mode is excited locally at r/a~0.6, the change in local magnetic shear contributes to the mode stabilization. The N|| scan indicates that the AE is stabilized when the magnetic shear exceeds a critical threshold. This tendency is consistent with the excitation theory of AEs.

Edge plasma behavior affected by energetic particle driven instabilities [4]

In Heliotron J, edge fluctuation has been studied using multiple Langmuir probes installed at different toroidal/poloidal sections. In low-density ECH plasma discharges with $n_e \sim 0.3\times10^{19}$ m^{-3}, a high correlation between floating potential signals measured with different probes was observed in the low frequency range less than 10 kHz. This fluctuation exhibits electrostatic characteristics. Radial structure of the fluctuation was investigated by fixing one probe inside LCFS and by scanning the other probe around LCFS in radial direction on a shot-to-shot basis. Clearly, the coherence is quite high ~0.95 inside LCFS in the low frequency range, and it quickly decreases outside LCFS. The phase difference in toroidal direction is almost zero in the observation range. This result presents similar characteristic to the long range correlation phenomena.

[1] S. Kobayashi, et al., "Experimental study of high density plasma operation in Heliotron J", 40th EPS, Espoo, Finland, 1-5 Jul. 2013, P1.148.
[2] T. Mizuuchi, et al., "Optimization of Fuelling Scenario for High Density Plasma in Heliotron J", Joint 19th ISHW and 16th IEA-RFP workshop, Padova, Italy, 16-20 Sep. 2013, K8.
[3] K. Nagasaki, et al., "Stabilization of energetic-ion-driven MHD Mode by ECCD in Heliotron J", Nucl. Fusion 53 (2013) 113041.
[4] S. Ohshima, et al., "Edge Plasma Behavior Affected by Energetic Particle Driven Instabilities in Heliotron J", Joint 19th ISHW and 16th IEA-RFP workshop, Padova, Italy, 16-20 Sep. 2013, O19.