Physics Research on the Heliotron J Confinement

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Heliotron J is a medium size, low shear, L=1 helical-axis heliotron (R=1.2m, a=0.2m, B<1.5T) with the magnetic well in the entire confinement region, which is equipped with several heating systems such as 0.4MW-ECH, 1.5MW-NBI and 0.5MW-ICRF. In Heliotron J, the operation regimes of the helical system can be extended by virtue of its flexible magnetic field spectrum control capabilities. This permits unique investigations of helical-axis heliotron optimization and provides a platform to study relevant theoretical models of the confined plasma behavior. To attain good compatibility between the drift optimization and the MHD stability, the bumpiness control is essential in Heliotron J. In this connection, the bumpiness effects on various aspects of plasma performance (bulk thermal confinement, high-energy particle confinement, plasma current control, particle fuelling, MHD, etc.) have been investigated these years. The results are reviewed in this paper.

By using ICRF minority heating, the fast ion formation and confinement was investigated in the low density condition of 0.4 x 10^{19}cm^{-3}. The fast ion flux (up to 30keV) measured by CX-NPA was largest in the high bumpy configuration under the experimental conditions of ICRF power 200-300KW. The electron cyclotron current drive (ECCD) experiments were carried out, focusing on the effects of the magnetic field ripple. The EC driven current decreased as the power was deposited at the deeper ripple bottom, and even the reversal of the current direction was observed, indicating that the amplitude and direction of EC driven current was determined by the balance between the Fisch-Boozer effect and the Ohkawa effect. The configuration effects on the bulk thermal confinement in NBI plasmas were investigated with regard to the bumpiness control. The preferable thermal confinement compared to the international stellarator scaling law ISS95 was obtained in the high and medium-bumpy configurations. The relevant improvement in the electron temperature was interpreted to mainly contribute to the enhancement of the plasma performance in the high- and medium-bumpy configurations. A gas fuelling by supersonic molecular beam injection (SMBI) was successfully applied to ECH/NBI plasmas, showing the peculiar characteristics such as increase (or decrease) of electron temperature and its target density dependence for ECH plasmas. For ECH(0.35 MW)+NBI(0.6 MW) plasmas, the stored energy reached about 4.5 kJ, which was about 50% higher than the maximum value achieved so far under the conventional gas-puffing control. The optimization of this fuelling method is now in progress. Data mining technique, which automatically extracts useful knowledge from the large dataset in Heliotron J, was applied to multichannel magnetic probe signals in order to identify and classify MHD instabilities. MHD instabilities were successfully classified using the criterion of phase differences of each magnetic probe and, as a result, identified as the energetic-ion-driven modes (GAE) from the related parameter studies including the bumpiness effects.

Finally, in the conference, these observations as well other phenomenology associated with the configuration control effects will be discussed in view of the development of the advanced helical system.