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Studies of Magnetic Field Configuration in Heliotron J

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The optimization of the magnetic field configuration is very important for helical systems since ripple loss in the collisionless regime should occur for simple stellarator/heliotron. There are various advanced concepts proposed to avoid such a loss adding good MHD stability. Heliotron J belongs to a quasi-omnigeneous concept among them, and is a low-shear helical-axis heliotron (major radius of the torus R_0 = 1.2 m, minor radius of the plasma a = 0.1-0.2 m, magnetic field on the axis $B_0 \leq$ 1.5 T, helical-coil pole number L = 1, pitch number M = 4) [1, 2]. Using controllable five sets of coil systems, Helitoron J realizes a wide range of configurations by changing the coil-current ratios. In this paper, the results of the control experiments by changing the bumpiness in the field configuration, which is one of the Fourier components in the Boozer coordinates, are described for (i) high energy ion confinement using ICRF minority heating and NBI heating, and (ii) energy confinement and electron internal transport barrier (eITB) for ECH or NBI plasmas. The configurations used in this study are as follows; the bumpiness (B_{04}/B_{00}, where B_{04} is the bumpy component and B_{00} is the averaged magnetic field strength) are 0.15 (high), 0.06 (medium) and 0.01 (low) at the normalized radius of 0.67, respectively.

The high bumpiness is best in the generation and confinement of fast ions among the three bumpinesses for the ICRF heating and fast ions up to 34 keV were observed by using the charge-exchange neutral particle analyzer (CX-NPA), where the ion temperature of target ECH plasmas were blow 200 eV and the electron line-averaged density of less than 0.5×10^{19} m^{-3}. For the extension of the energy range, the combination heating of ICRF and NBI is attempted in the low-ε_t and the high-bumpiness configurations in the medium density operation (1×10^{19} m^{-3}). The low-ε_t configuration is considered to be good confinement from the previous experiment and also expected to have good confinement from the neo-classical theory. Here, the toroidicity and the bumpiness normalized by the helicity for the low-ε_t and the high-bumpiness configurations are (0.77, -1.04) and (0.86, -1.16) in Boozer coordinates, respectively. When the ICRF pulse is imposed, the high-energy tail component is substantially increased up to 60 keV in the low-ε_t configuration. In the high bumpiness, the energy spectrum is different from the low-ε_t and limited within 35 keV in this condition.

The energy confinement time for ECH or NBI plasma was also studied. The enhancement factor of energy confinement time for the ISS95 scaling was about 1.8, 1.7 and 1.4 for NBI plasmas in the high, medium and low bumpy configuration, respectively. However, the medium bumpiness was most favorable for ECH plasmas in the experiment of the same density range. The dependence of electron internal transport barrier (eITB) was also investigated in ECH plasmas. The effective ripple, ε_{eff} of the high and low bumpiness is slightly larger than that of the medium bumpiness in the core region where the eITB has been formed (ρ < 0.4). Because the eITB formation depends on the threshold plasma density, the density dependence on the eITB formation for the three magnetic configurations is investigated. The achieved $T_e(0)$ values of the three magnetic structures are almost same, whereas the threshold of the averaged density to form the eITB in the low and high bumpinesses is smaller (~0.6×10^{19} m^{-3}) than that of the medium bumpiness (~1.2×10^{19} m^{-3}). This means that the density region to form the eITB expands in the medium configuration.

References

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