Configuration Control Experiment in Heliotron J

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The optimization of the field configuration is very important for helical systems since there is large ripple loss in the collisionless regime for simple stellarator/heliotron. There are various advanced concepts proposed for this purpose. 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 or NBI, (ii) a bootstrap current and (iii) energy confinement 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.

High energy ions up to 30 keV were investigated by charge-exchange neutral particle analyzer (NPA) for both NBI ions and accelerated ions by ICRF. The former mainly includes passing particles and the latter, trapped particles. For both cases, the high energy ion confinement was improved by increasing bumpiness. The results of the analysis using Monte Carlo method roughly agree with the experiment results including pitch angle distribution of fast ions. The bumpiness can control the loss cone structure in this range of experiment. A non-inductive toroidal current plays an important role for Heliotron J since it could affect the transport through the field structure change whereas no current is required to form the confinement field. From this point of view, a bootstrap current was investigated in ECH plasmas. The bootstrap current ($\leq$ 2 kA) flowed in the co-direction in most cases. The current was largest in the high bumpiness and lowest in the low bumpiness. However, in low density region for the low bumpiness, the flow direction was reversed. This current reversal is explained by the neo-classical theory taking account of the expected radial electric field. 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 in the high, medium and low bumpy configuration, respectively. However, the medium bumpiness was most favourable for ECH plasmas in the experiment of the same density range. This difference is under investigation. The change of the field structure by the beam driven current and the change of the confinement of fast ions are the candidates for this explanation.

[1] F. Sano et al., J. Plasma and Fusion Res. Series, **3** (2000) 26.
[2] T. Obiki et al., Nucl. Fusion, **41** (2001) 833.