§5. Control of Rotational Transform by Electron Cyclotron Current Drive in Helical Systems

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Noninductive current plays an important role in the realization of high-performance plasmas and the sustainment of steady-state plasmas in toroidal fusion devices. In stellarator/heliotron (S/H) systems, no Ohmic current is required for equilibrium since the confinement magnetic field is generated by external coils. However, it is known that noninductive current flows in S/H systems as well as in tokamaks. Both bootstrap and Ohkawa currents modify the rotational transform profile, thereby affecting the equilibrium and stability. In S/H systems, electron cyclotron current drive (ECCD) is expected to be an effective current drive scheme to suppress the non-inductive current and to tailor the rotational transform profile, particularly in low-shear devices. From the viewpoint of diagnostics, S/H systems have the advantage of allowing precise measurement of the EC driven current. Because no Ohmic current is required in S/H systems, they achieve an accuracy of 0.1 kA using conventional Rogowski coils. Comparing experimental results between tokamaks and helical systems gives us a deeper understanding of the ECCD physical mechanism in toroidal devices.

ECCD experiments have been performed in the medium-sized device, Heliotron J [1]. Plasmas are produced and heated by 70-GHz second harmonic X-mode ECH. We have installed an upgraded EC launching system in order to extend the controllability of EC driven current [2]. An ECH power of 260 kW is injected up to 140 msec. Figure 1 shows the EC driven current as a function of $N_{\|}$ in three configurations. The EC driven current numerically calculated by the TRAVIS code is also plotted. TRAVIS [3] is a ray tracing code for ECH/ECCD and ECE diagnostics in arbitrary 3D magnetic configurations, in which the CD efficiency is calculated by applying the adjoint approach with parallel momentum conservation (PMC) taken into account. For high and medium h configurations, the EC driven current increases with $N_{\|}$ in the Fisch-Boozer direction. For the low h configuration (h = 0.82), the EC driven current is nearly zero, independent of $N_{\|}$. The $N_{\|}$ dependence in three configurations indicates that the EC current is more strongly driven when the power is deposited at the high field position in the magnetic ripple structure, and it is suppressed when the EC power is deposited at nearly the bottom of the magnetic field ripple. The TRAVIS calculation reproduces the $N_{\|}$ dependence well in all three magnetic configurations considered in the experiments, though there is uncertainty in the input parameters such as the n_e and T_e profiles and the effective charge.

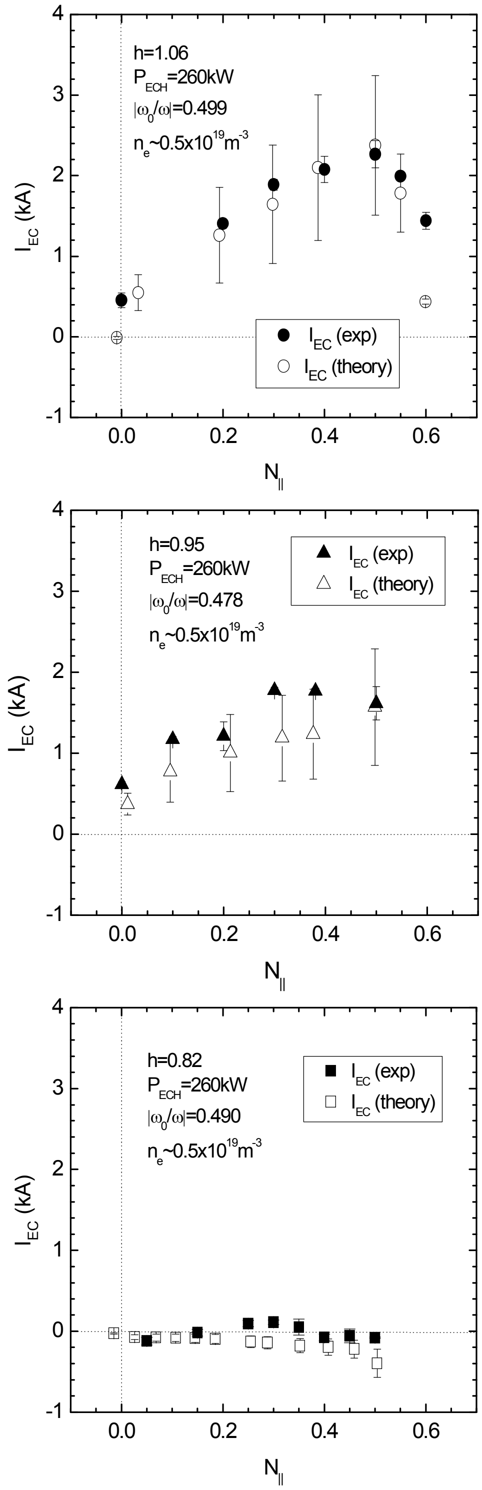

Fig. 1. $N_{\|}$ dependence of EC current in three configurations (h=1.06, 0.95 and 0.82). The closed and open symbols denote the experimental and theoretical EC driven current, respectively.

1) K. Nagasaki, et al., submitted to Nucl. Fusion
2) K. Nagasaki, et al., Contrib. Plasma Phys. **50** (2010) 656.
3) N. B. Marushchenko, et al., Phys. Plasmas **18** (2011) 032501.