§48. Study on Physical Process of Electron Cyclotron Current Drive

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In stellarator/heliotron (S/H) systems, few attentions have been paid to toroidal current, since it is not required for plasma equilibrium. However, recent experimental results show that bootstrap current is driven by pressure gradient, affecting the plasma equilibrium and stability. It is recognized that even small current of a few kA should be controlled particularly for low shear S/H systems. We have performed international collaboration research on ECCD in Heliotron J (Kyoto Univ.), CHS (NIFS) and TJ-II (CIEMAT) [1], and it was found that the EC driven current is at the order of 1 kA in three devices and the normalized current drive efficiency is almost the same within the factor of two. The purpose of this study is to clarify the physical process of ECCD commonly observed in S/H systems by comparing the experimental results with theory.

In order to investigate the effect of EC driven current on the rotational transform, we have calculated the rotational transform profile by including the poloidal magnetic field generated by ECCD. We assume that plasmas are cylindrically symmetric, and the EC driven current profile is Gaussian, and its HWHM is 0.1 and its peak position is 0.1.

Figure 1 shows the calculation results on the effect of ECCD on rotational transform profile in an LHD configuration. Since the inductive current is not included in the calculation, these profiles correspond to steady state. It can be seen that for co-ECCD of 5 kA the central rotational transform increases and the negative magnetic shear is formed. The poloidal magnetic field is much lower than the toroidal current at the central region, even small current strongly affect the rotational transform if the current is driven in localized area. Such a situation should occur in the experiment, since this order of EC driven current has been observed in the LHD experiment. For ctr-ECCD, on the other hand, the central rotational transform decreases, and the positive magnetic shear is stronger. The central rotational transform approaches zero or negative at 10 kA. For both co- and ctr-ECCDs, the edge rotational transform changes little unless the current of larger than 50 kA flows. This is because the original poloidal magnetic field is strong at the edge region, comparable to the toroidal magnetic field. These results indicate that localized ECCD is an effective scheme to control the rotational transform profile to avoid low order rational surfaces at low shear region. The effect of rotational transform on global confinement will also be possible to investigate in the experiment.

ECCD experiments have been carried out in LHD [2]. The observed EC driven current flows in the Fisch-Boozer direction, and depends on the parallel refractive index. Rotational transform profile has been measured in LHD by Motional Stark Effect diagnostic. Co-ECCD increases the central rotational transform, and ctr-ECCD decreases it. This tendency qualitatively agrees with the direction of poloidal magnetic field generated by the measured EC current. The current drive efficiency, $\gamma = n_e R I_p / P_{abs}$ is estimated to be 9×10^{17} A/Wm^2.

In the future, we will carry out analysis of time evolution of rotational transform profile by including inductive current which has an important role on the determination of the rotational transform profile within the current diffusion time.

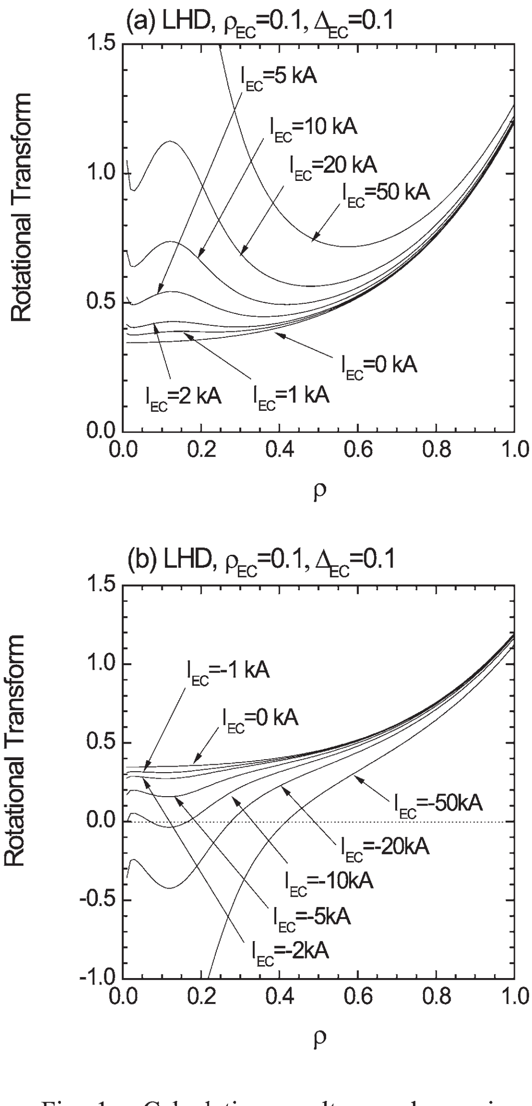

Fig. 1. Calculation results on change in rotational transform profile by ECCD, (a) co-ECCD and (b) ctr-ECCD

1) Nagasaki, K., et al.: Plasma Fus. Res. **3** (2008) S1008
2) Yoshimura, Y., et al.: submitted to Plasma Fus. Res.