§16. The Observation of the Negative Toroidal Current in Heliotron-J

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In helical devices, net toroidal currents are not required to produce magnetic field for plasma confinement, while theoretical prediction suggests that there are several kinds of net toroidal currents, that is, bootstrap current, beam driven current and microwave driven current. Even if these toroidal currents are sufficiently small to activate current driven instabilities, they can affect the characteristics of the magnetic configurations. The Heliotron-J device (H-J) is quit suitable to study the driving mechanism of toroidal current in helical devices because there we can make the operation with various magnetic configurations more easily comparing with other helical devices. Here we show an experimental result on the bootstrap current in H-J.

Figure 1 shows the dependence of the observed toroidal current and the plasma stored energy on the electron density in H-J ECH plasmas. Various symbols in Fig.1 correspond to the various bumpiness configurations. The bumpiness increases in the order of circles, squares and triangles. In the all configurations, the toroidal currents decreases with the plasma stored energy. The fact is consistent with the BS current behavior. However, for the smallest bumpiness configuration, the observed toroidal current flow in the negative direction (to reduce the rotational transform) and the amplitude of the toroidal current increases with the density decrease in the low density region with $n_e<0.6\times10^{19}m^{-3}$. Figure 2 shows the observed toroidal current and the prediction of BS current by SPBSC code [1] under the assumption of $E_r=0$ in a density range with $n_e\sim0.6\times10^{19}m^{-3}$. In the calculation, the electron and the ion temperature are assumed $T_e=600\text{-}700eV(1-\rho^2)^2$, $T_i=150\text{-}200eV(1-\rho^2)^2$, respectively. The electron density is assumed as $n_e\sim(1-\rho^6)$. Here is a normalized minor radius. B_{04}/B_{00} denotes the amplitude of the bumpy component. In a large bumpiness configuration, the predicted BS current with $E_r=0$ is almost consistent with the observation in both the direction and the amplitude. In a small bumpiness configuration, the predicted BS current with $E_r=0$ is inconsistent with the observation in the direction. In the higher density case, even in a small bumpiness configuration, the predicted BS current with $E_r=0$ is almost consistent with the observation. In Fig.2, the radial electric field is assumed as $E_r=0$. However, in the plasma with different collisionalities between electrons and ions, it is pointed out that the BS current proportional to the radial electric field in the helical systems because the geometric factors depend on the collisionalities in helical systems [2]. In the low-density ECH discharges, the positive electric field is expected [3], which suggests that a cause of the negative current in Figs.1 and 2 would be radial electric field. In Fig.3, the theoretical prediction of BS current under an assumption of E_r is shown. Here the electric potential profile is assumed proportional to the electron temperature. As the central electric potential increases, the prediction of BS current decreases and the sign becomes negative. In the case that the central electric potential is larger by 3 times than the electron temperature, the prediction of BS current would be as large as the observed toroidal current. According to the calculation with some density profile, the density profile effect on the BS current is not so large in the discharge condition in Fig.2.

In order to confirm the above-mentioned cause of the observed negative toroidal current, ECCD effects and super-thermal effects should be eliminated. This is one of the future subjects.

Reference

[1] K.Y.Watanabe et al, Nucl.Fusion 35(1995)335.
[2] N.Nakajima et al, J.Phys.Soc.Jpn 61(1992)833.
[3] H.Idei et al., Phys.Rev.Lett. 71, 2220 (1993).

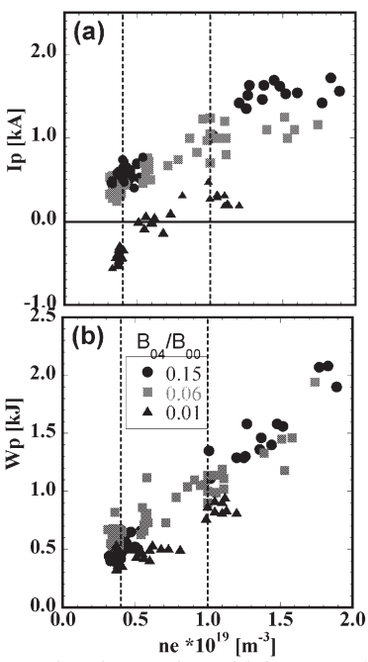

Fig.1 The observed toroidal current (a) and the plasma stored energy vs. the electron density.

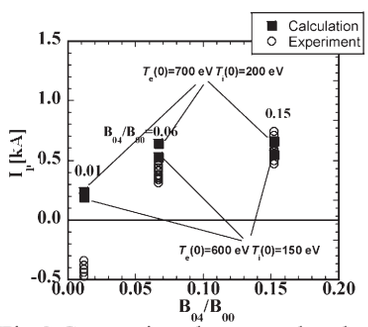

Fig.2 Comparison between the observed toroidal current and the predicted BS current with $E_r=0$ in $n_e\sim0.4\times10^{19}m^{-3}$.

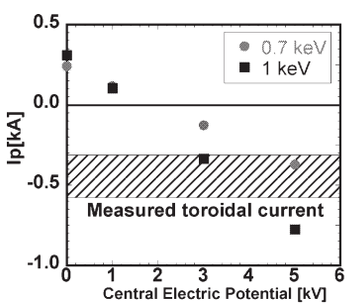

Fig.3 The dependence of the predicted BS current on E_r ($B_{04}/B_{00}=0.01$).