§22. Study of the Driving Mechanism of Toroidal Current in Heliotron-J

Watanabe, K.Y.
Motojima, G., Okada, H., Nakamura, Y., Sano, F. (Kyoto Univ.)

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. In the low magnetic shear devices, appearance of the low order rational magnetic surface due to the toroidal current might lead to a big island structure and/or the degradation of the confinement. Even in the devices with a finite magnetic shear, the net toroidal currents with direction increasing the rotational transform lead to the decrease in the magnetic shear and the suppression of Shafranov shift, which restrains the formation of magnetic well. Then, the study of the driving mechanism of toroidal current in helical devices is important.

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. Table.1 shows the advantage of the H-J from viewpoint of study on the driving mechanism of toroidal current. Here we show an experimental result on the bootstrap current in H-J.

Figure 1 shows the dependence of the bumpy component of magnetic field strength on the observed toroidal current in the NBI+ECH plasmas. Here the electron densities are almost same. Circles and squares denote the observation and the bootstrap current of the theoretical prediction, respectively. Here the bumpiness of the magnetic field changes by 5 times, but the toroidal ripple and helical ripple of the magnetic field are almost same within less than 5%. The theoretical prediction is calculated by the SPBSC code [1], which is based on a momentum approach proposed by Shing et al [2]. The increase of the current with the bumpiness is observed in both the experiment and the prediction. However, the current value itself in the experiment is larger than the prediction. The reason is why the Ohkawa current exits in the experiments. The estimation of the Ohkawa current is one of the future subjects.

According to the neoclassical transport theory in the asymmetrical devices, the existence of the neoclassical current proportional to the radial electric field is predicted when the ion collisionality is different from the electron one. The above current exists only in asymmetrical devices like H-J. In ECH discharges, the electrons and the ions are expected to belong to the 1/ν and the plateau collisional regimes, respectively, and the radial electric field becomes the positive [1,3]. There the negative neoclassical current is expected. Figure 2 shows the time trace of the observed toroidal current and the electron density in ECH discharges. In the latter phase of the discharges, the electron density rapidly diseases and the observed toroidal current becomes negative. This behavior is consistent with the theoretical prediction based on the neoclassical current proportional to the radial electric field. In the low density, the super-thermal effect ob ECCD cannot be ignored yet. The qualitative estimation of the neoclassical current proportional to the radial electric field is under the consideration.

Reference
1) K.Y.Watanabe et al, Nucl.Fusion 35(1995)335.
2) K.C.Shaing and J.D.Callen, Phys. Fluids 26(1983)3315.
3) N.Nakajima et al, J.Phys.Soc.Jpn 61(1992)833.

H-J	LHD
1. Easy to change the bumpiness of B 2. L/R period is shorter than a typical discharge time, (especially in ECH)	1. Ion collisionality becomes low. 2. Existence of powerful profile measurement 3. Because magnetic structure is simpler than H-J, it is easy to analyze it.

Table.1 Characteristics of H-J and LHD from viewpoint of study on the driving mechanism of toroidal current

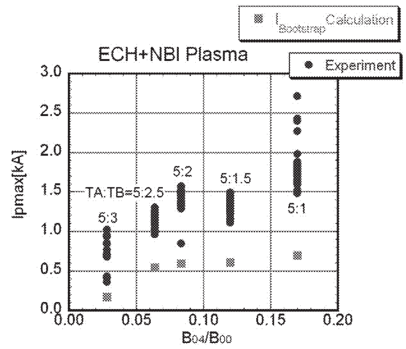

Fig.1 The observed toroidal current dependence on the bumpiness of B (NBI+ECH discharge).

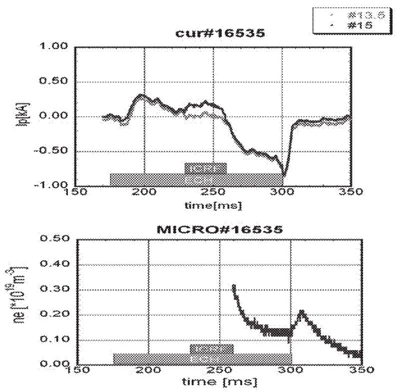

Fig.2 Time trace of observed toroidal current (top) and the electron density (bottom) (ECH, B_{04}/B_{00}~0.03)