§23. Dependence of the Bootstrap Current on the Radial Electric Field in Heliotron-J and LHD

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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 (BS) current, beam driven current and microwave driven current. 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 BS current in H-J. In order to obtain the systematic knowledge of the BS current behavior in the helical plasmas, we systematically study the dependence of the observed current in H-J on the various parameters, and the results are compared with LHD experimental results. Here we are focusing on the radial electric field, E_r.

In H-J, it is reported that the negative toroidal current is observed in the low-density operation, and its direction is opposite to the theoretical prediction of the BS current with E_r=0 [1]. In ref.[1], the negative toroidal current is considered due to the BS current taking E_r>0 into account and/or the density dependence of ECCD. According to a theoretical prediction [2], in the plasma with different collisionalities between electrons and ions, it is pointed out that the BS current proportional to E_r in the helical systems because the geometric factors depend on the collisionalities in helical systems, and that, in the positive E_r, the BS current should be negative. In order to distinguish the contributions between the ECCD and BS current to the observed toroidal current in LHD, we compare between the net toroidal current with B_0>0 and B_0<0 as shown in Fig.1. Here the directions of the ECCD are same between the discharges with B_0>0 and B_0<0. Circles and squares denote the observed toroidal current with B_0>0 and B_0<0, respectively. Under the assumption that the contributions of the ECCD are same, those of the BS current are quantitatively same but the signs are opposite in the discharges with B_0>0 and B_0<0, the contributions of the ECCD and the BS current are estimated as shown by the dashed line and the solid line in Fig.1. From this result, we can confirm strongly that the BS current should change the sign due to E_r.

In order to examine the accuracy of the theoretical model of BS current on E_r, we need the density, the temperature and the E_r profiles. However, H-J does not have the capability to measure the above plasma parameters now. Then we made the experiments on the E_r effect of BS current in LHD. LHD belongs to the helical devices, and it has the quite different magnetic configuration from H-J. However, there the negative BS current due to E_r<0 is also predicted. The advantage of LHD is the capability of the powerful profile measurement systems. On the contrary, the LHD is not suitable to study the toroidal current evolution in ECH plasmas because the duration time of the ECH is shorter than the toroidal current saturation time, and it is not easy to estimate the amplitude of non-inductive current. Figure 2 shows the Dependence of the net toroidal current on the plasma-stored energy in LHD. Circles and triangles correspond to the saturation current and the current at the end of the discharge, respectively. In the case of triangles, the non-inductive current is expected to be higher than the shown data in Fig.2. Solid line corresponds to the theoretical prediction of the BS current with E_r=0. In Fig.2, W_p is almost proportional to the density. From W_p=40kJ to 60kJ, the observed current increases with W_p, which is consistent with the BS current with E_r=0. However, around W_p=30kJ, the saturated current suddenly decreases and its sign changes. According to the profile measurements, T_i/T_e~0.83 and E_r<0 at ref.2 in Fig.2, and T_i/T_e~0.29 and E_r~T_{e0}/a_p at ref.1. In the case of ref.1, the ion and the electron is expected to belong to the plateau and 1/ν collisional regime, respectively. The negative current at ref.2 in Fig.2 would be due to the BS current with E_r<0. For the more detailed analysis, the analysis of the time evolution of the toroidal current profile and the accurate E_r measurement would be necessary. These are our future subjects.

Reference
[1] G.Motijima et al, Fusion Sci. Technol. 51(2007)122.
[2] N.Nakajima et al, J.Phys.Soc.Jpn 61(1992)833.

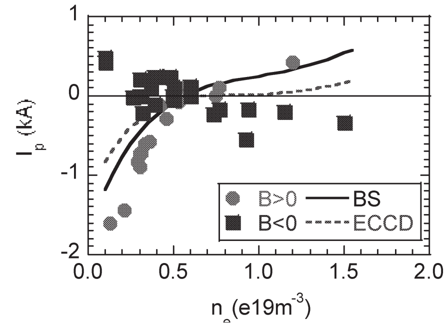

Fig.1 Dependence of the net toroidal current on the density with B_0>0 and B_0<0 in H-J.

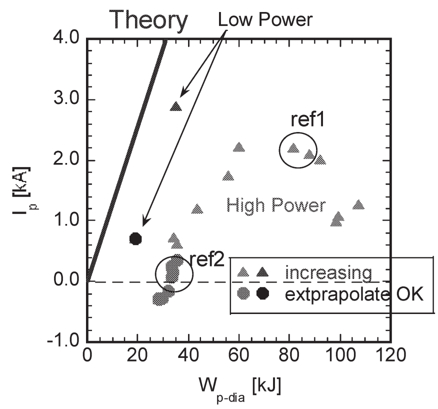

Fig.2 Dependence of the net toroidal current on the plasma stored energy in LHD.