§5. Observation of Spontaneous Toroidal Flow Driven by Ion Temperature Gradient on LHD

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Toroidal flow contributes to stabilization of a resistive wall mode is pointed out in tokamaks. Spontaneous toroidal flow becomes important in the next fusion device such as ITER where the toroidal flow velocity driven by external momentum is expected to be not enough for stabilizing the MHD mode. The mechanism of driving the spontaneous toroidal flow gathers a great interest in physics of momentum transport and has been investigated in tokamaks experimentally and theoretically.

We have studied formation mechanisms of spontaneous toroidal flow on the LHD, and clearly observed that the spontaneous toroidal flow is driven in the counter direction with positive radial electric field at the plasma edge while it is driven in co-direction near the plasma core in the 10th campaign. In the 11th campaign, the spontaneous toroidal flow driven with ion temperature gradient has been investigated.

The ion temperature gradient is controlled by changing the heating power for the plasma (R_{ax}=3.75m, B=2.64T, γ=1.254). Profiles of the toroidal flow velocity are measured with charge exchange spectroscopy (CXS) using the charge exchange line of carbon impurities (CVI). The line averaged electron density of 1×10^{19} m^{-3} is kept constant during the discharges and there is no significant change of the radial electric field.

Figure 1 (a) and (b) shows the profiles of the ion temperature T_i and the toroidal flow velocity V_T, respectively, when the number of NBI is changed. Steep gradient of the ion temperature is produced by increasing the heating power, and the profile of the toroidal flow velocity clearly changes around the R=4.3 m as shown in Fig.1 (b). The toroidal flow in the co-direction is supposed to be increased associated with the increasing of ion temperature gradient. The dependence of the toroidal flow velocity on the ion temperature gradient at the R=4.35m is shown in Fig.1 (c). The offset, a finite value of V_T without the gradient of T_i, is considered to be due to the other driving terms of the spontaneous toroidal flow besides the ion temperature gradient, such as density gradient and radial electric field E_r. The direction of the grad-T_i driven flow is anti-parallel to that of tokamaks observed at ITB [1, 2] and is parallel to that observed in the ICRF and the ohmic H-mode on the Alcator C-Mod [2]. There is strong connection between toroidal flow and E_r in tokamaks. It is, accordingly, difficult to distinguish between effects of the gradient T_i and effects of the E_r on the toroidal flow. The toroidal flow driven by the ion temperature gradient is clearly observed in the large helical device.

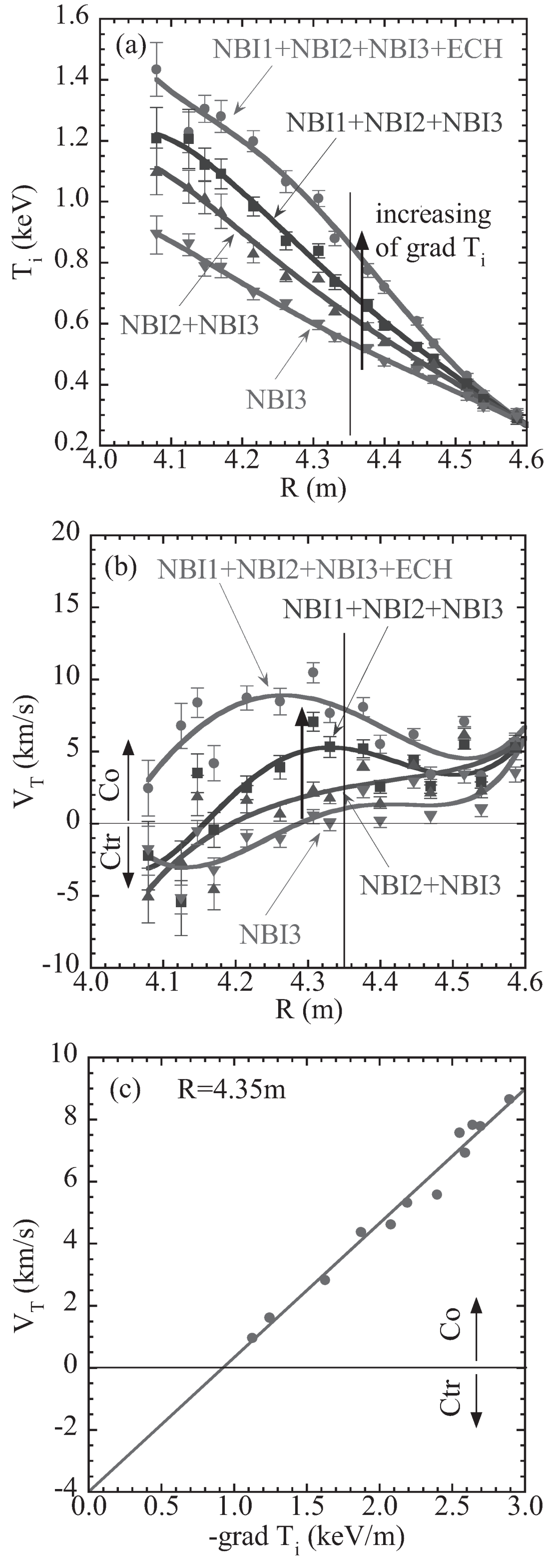

Fig. 1. Radial profiles of (a) ion temperature and (b) toroidal flow velocity with changing the heating power. (c) Dependence of the toroidal flow velocity on the gradient of the T_i at the plasma edge (R=4.35m).

1) Y.Sakamoto, et al., Nucl.Fusion, **41**(2001) 865.
2) J.E.Rice, et al., Nucl.Fusion, **41**(2001) 277.