§2. Time Evolution of Troidal Flow in Beam Switch Discharges on LHD

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There is great interest in the driving mechanism of the spontaneous toroidal flow and the momentum transport physics to control the toroidal flow profiles. It is observed that there are both NBI driven toroidal flow and spontaneously driven toroidal flow due to the steep gradient of T_i in the high T_i discharges on large helical device (LHD). There are difficulties in identification of the contribution of the spontaneously driven component to the toroidal flow because the NBI is not balanced in the discharges and there is steep gradient of T_i which is considered to be driving source of the spontaneous toroidal flow. In order to obtain an information of how the toroidal flow is driven with the NBI in LHD plasma, time evolutions of toroidal flow profiles are observed when the NBI is switched from co-direction or counter-direction to the opposite in the low T_i plasmas in which the spontaneous component is considered to be small.

In this experiment, the plasma is produced and sustained with NBI and the magnetic axis R_{ax} of 3.6m and the magnetic field strength B of -2.75T. The electron density is $1 \times 10^{19}\mathrm{m}^{-3}$. The toroidal flow profiles have been measured with charge exchange spectroscopy. LHD equips three tangentially injected NBI (BL1, BL2, and BL3) and BL1 and BL3 direct to co-direction and BL2 directs to counter-direction under the reversed magnetic field configuration, where the co-direction and the counter-direction are defined as the parallel and anti-parallel to the equivalent toroidal plasma current, respectively. In the beam switch discharges, the direction of the momentum input is changes from co (counter) to counter (co) by replacing one NBI to other which directs opposite direction at t=4.8 sec.

Figure 1 shows the time traces of toroidal flow velocity near the plasma center in the case of beam switch from BL3 to BL2 with and without BL1 injection. Firstly, the toroidal flow is driven toward co-direction corresponding to the direction of injected NBI, then the velocity changes toward counter-direction after the beam switch. The time scale of the velocity change toward the co-direction at t=3.6 sec in the case with BL1 is match faster than that predicted from the time scale in the case without BL1 and additional torque with BL1. The velocity change toward the counter-direction rapidly just after the beam switch in the both cases with and without the BL1. It is also observed the slower decay or change of the velocity after the rapid change of the velocity in the case with BL1 . Although the change of the torque input from NBI at the beam switch is identical between in the cases with and without BL1, the change of the velocity after the beam switch in the case with the BL1 ($\Delta V_T \sim$ 40km/s) is slightly larger than that in the case without the BL1 ($\Delta V_T \sim$ 30km/s). These observations suggest that there is contribution of the spontaneous toroidal flow to the toroidal flow in the case with BL1. The gradient of ion temperature in the case with BL1 is larger than that in the case without BL1. Archived velocity with co-injection phase is larger than that with counter-injection phase in the case without BL1. Thus the asymmetricity is observed in the toroidal flow production with the tangential NBI.

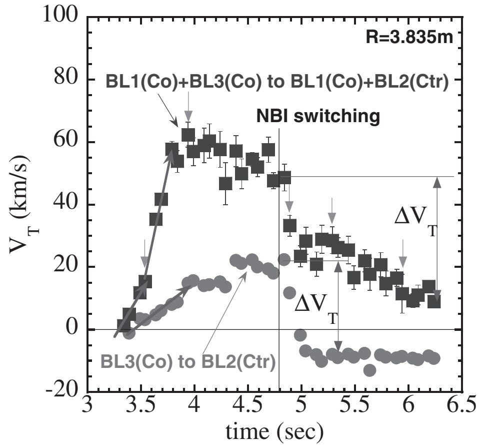

Fig. 1: Time trace of toroidal flow velocity in the case of beam switch from BL3 to BL2 with (square) and without (circle) BL1 injection.

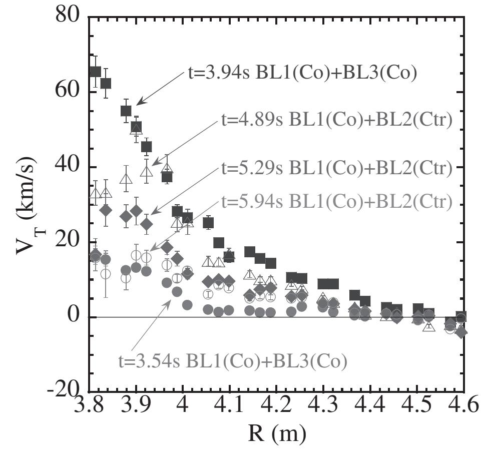

Fig. 2: Radial profiles of toroidal flow velocity at the time indicated with the down arrows in Fig.1.

Figure 2 shows the evolution of radial profiles of toroidal flow velocity during the beam switch discharge with BL1. The peaked profile of the velocity with steep gradient around $R = 4$m is produced from the beginning of the discharge and the steep gradient kept in the decay phase after the beam switch except the last profile at $t = 5.94$s. The steep gradient disappears during the time between 5.29s and 5.94s at where the velocity near the center decays slowly as shown in Fig.1. There are interest behaviours of toroidal flow velocity in the beam switch discharges for momentum transport studies.