18PB-029

Observation of Toroidal Flow Formation on LHD
LHD装置におけるトロイダル流形成過程の観測

M. Yoshinuma, K. Ida, K. Nagaoka, and LHD Experiment Group
吉沼幹朗, 居田克巳，永岡賢一, LHD実験グループ

National Institute for Fusion Science
322-6, Oroshi-cho, Toki 502-5292, Japan
核融合科学研究所 〒502-5292 土岐市下石町322-6

Time evolutions of toroidal flow in the plasma after the injection of the tangentially directed neutral beams are observed to investigate the birth and evolutions of the spontaneous component in the toroidal flow. The spontaneous component is increased monotonically while the ion temperature and its gradient change rapidly and then change gradually after the injection of tangentially directed neutral beams. It is suggested that the observed spontaneous component is not coming from the ion temperature or ion temperature gradient directly.

1. Introduction

Flow structure in the plasma has been considered to be an important for the transport in magnetic confinement devices. It has been pointed out that the toroidal flow contributes the stabilization of resistive wall mode in tokamaks. There is, therefore, a great interest in the mechanisms of the driving of spontaneous toroidal flow and the momentum transport physics to control the toroidal flow structure. It has been observed that there are both NBI driven toroidal flow and spontaneously driven toroidal flow due to a steep gradient of ion temperature in the high ion temperature discharges in the large helical device (LHD) [1]. And it is also observed that the toroidal flow is damped with the stochastization of the magnetic field duet to the reduction of magnetic shear by the neutral beam injection. So, it is unusual that the toroidal flow is driven simply to co-direction or counter-direction by injection of the co-directed neutral beam or counter-directed neutral beam, respectively. In order to investigate the mechanisms of the toroidal flow formation in the LHD plasma, it is important to find the behaviors of the spontaneous component in the toroidal flow formation distinctly from the external driven component. The development of an asymmetry in the toroidal flow with the neutral beams injection is shown in this presentation.

2. Experiment and Results

The plasma is produced with electron cyclotron heating (ECH) and sustained with perpendicularly injected neutral beam (P-NBI). The toroidal flow profiles have been measured with charge exchange spectroscopy (CXS) and the P-NBI is modulated on and off to acquire the background signals for the CXS measurement [4]. The magnetic axis and the magnetic field strength in this experiment are 3.6m and 2.74T, respectively. The magnetic axis position of 3.6m is applied for the high ion temperature discharge in LHD [2, 3]. The electron density is 2-3x10^{19} m^{-3}. We can avoid the damping of the toroidal flow with the stochastization of the magnetic field observed in LHD by using a bit higher electron density than the 2.0x$10^{19}m^{-3}$. LHD equips three tangentially directed NBI (N-NBI). One of the tangentially injected beams (BL2) is directed to co-direction and the others (BL1, BL3) are directed to counter. Co-direction and counter-direction are defined as the parallel and anti-parallel to the equivalent toroidal plasma current, respectively. The injection of the tangential NBI starts at the time of 3.8s.

Figure 1 (a) and (b) show the time evolutions of ion temperature at the plasma center and the gradient of the ion temperature near the mid-radii of the plasma, respectively. The time evolutions in the case of co-injection and counter-injections are plotted as circles and squares, respectively. The ion temperatures are increased after the injection of the tangential neutral beam in both cases. The gradients of an ion temperature are also increased with the injection of tangential NBI. There is no significant difference in the time evolutions of ion temperature and its gradient between the co-injection case and the counter-injection case. The ion temperatures and its gradients are increased rapidly (~100 msec) and then increased gradually with a time scale of a few hundred milliseconds. There are two different time scales in the time evolution of the ion temperatures and its gradients after the injection of the N-NBI.

Figure 1 (c) shows the time evolutions of toroidal flow at the plasma center in both cases of co-injection and counter-injection. The toroidal flows are increased rapidly to the same direction of the injected neutral beams just after the injection. The absolute values are almost same at t=4s in both cases. It is considered that the symmetrically driven components of the toroidal flow are the toroidal flows driven by the external momentum input due to the neutral beam injection. After the rapid change of the neutral beam driven component, the toroidal flow velocity changes gradually toward the co-direction in both cases. It should be noted that the co-direction is an opposite to the direction of the injected beam in the case of the counter-injection. The gradually increased toroidal flows, which are driven in co-direction in both cases, are considered to be a spontaneous component.

Time evolution of averaged values of flow velocity in both two cases is plotted as triangle symbols in Fig.1 (c) to clearly observe the time evolution of the spontaneous component. The spontaneous component is increased monotonically while the ion temperature and its gradient change rapidly and then change gradually after the injection of N-NBI. It is suggested that the observed spontaneous component is not coming from the ion temperature or ion temperature gradient directly.

Acknowledgments

We would like to thank members of the technical staff for their effort to support the experiment on the LHD. This work is supported by National Institute for Fusion Science grant administrative costs, ULHH022.

References

[1] M. Yoshinuma, K. Ida, et al.: Fusion. Sci. Technol. **58** (2010) 103.

[2] O. Kaneko, M. Yokoyama, et al.: Plasma and Fusion Res. **4**(2009) 027

[3] K. Nagaoka, K. Ida, et al.: Nucl. Fusion **51** (2011) 083022

[4] M. Yoshinuma, K. Ida, et al: Fusion. Sci. Technol. **58**(2010) 375.

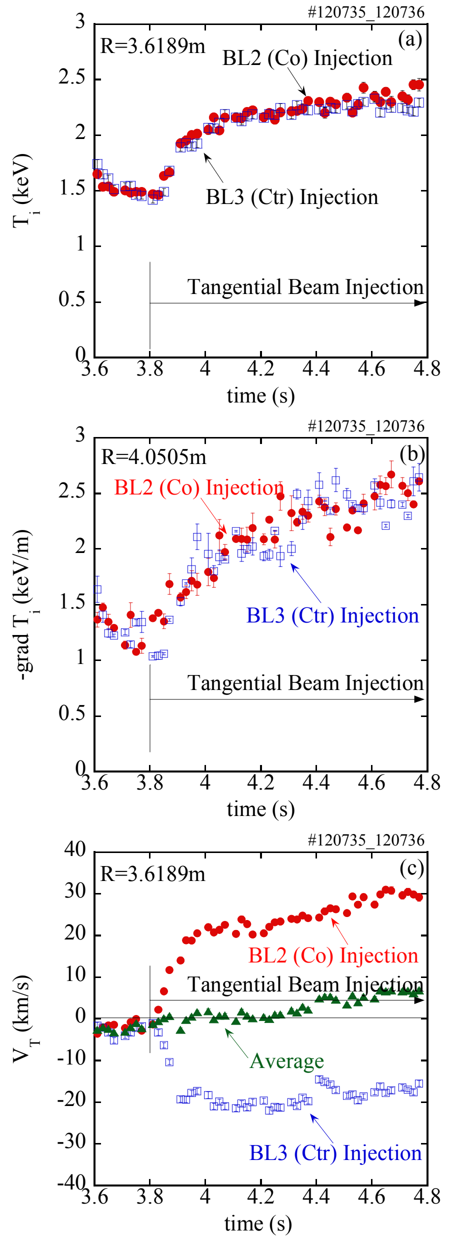

Fig.1. Time evolutions of (a) ion temperature near the plasma center, (b) gradient of ion temperature near the mid-radii of the plasma, and (c) toroidal flow velocity at the plasma center in the case of co-directed beam injection (red circle) and counter-directed beam injection (blue square). Averaged values of the toroidal flow for co-injection and counter-injection case are plotted as green triangles.