§67. Effect of Ripple Trapped Electrons on Neutral Beam Driven Current in LHD

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Recently, the control of plasma current and/or iota profile is recognized to be important for confinement improvement not only in tokamaks but also in stellarators. The basic properties of neutral beam driven current have been experimentally investigated in LHD. In this report, the results of neutral beam current drive experiments in 9th campaign of LHD, in particular, the effect of ripple trapped electrons on the neutral beam driven current are experimentally investigated by changing plasma shape.

Three neutral beam injectors has been tangentially installed in LHD, and long pulse beams with the duration of about 5 second have been injected for the neutral beam current drive (NBCD) experiments. The hydrogen gas puffing has been used to keep the plasma density constant during the discharge, and the saturation of plasma current has been evaluated. The magnetic configurations of this NBCD experiment is Rax=3.6m, Bt=1.5T and Bq=72-200%, where Bq is scanned in order to change plasma shape, that is, magnetic ripple. The plasma current includes two components; one is bootstrap current and the other neutral beam driven current. In order to evaluate the latter, discharges with co- and ctr-injection NBI have been compared.

In general, neutral beam driven current is given by

$$I_{NB} = \frac{I_b V_b \tau_S}{2\pi R}\left(1 - \frac{1}{Z_{eff}}G\right) = I_{NB0}\left(1 - \frac{1}{Z_{eff}}G\right) \quad (1)$$

where I_b, V_b, τ_S, Z_{eff} and G are neutral beam current injected by NBI, beam velocity, slowing down time of injected ions, effective charged number of bulk plasma ions and geometrical factor, respectively. In LHD case, slowing down time of beam ions is dominated by collisions with electrons, so it depends on electron temperature and density ($T_e^{3/2}/n_e$). For simplicity, electron temperature on the magnetic axis and line averaged density experimentally obtained have been used to evaluate I_{NB0}. The current drive efficiency (I_{NB}/I_{NB0}) is considered to depend on G, because it may be considered that Z_{eff} does not depend on the plasma shape, which is shown in Fig.1. The geometrical factor approximates ratio of toroidally circulating electron f_c and depends on the magnetic configuration. The larger ratio of circulating electron, the smaller neutral beam driven current, because circulating electrons produce retarding current against the beam current. The dependence of volume averaged ratio of circulating electron $< f_c >$ is also shown in Fig.2. The plasma destabilizes and can not be applied the ctr-current in the plasma with ctr-NBI heating in the case of Bq=200%. The error bar becomes large because the plasma current can not be scanned in wide range. Thus, It is difficult to conclude whether the model given by eq.(1), which is also shown with dotted line in fig.2, can be applied for helical devices. The wider range scan of Bq in small Bq region is necessary for getting the clear experimental confirmation, which is planed in the LHD 10th campaign.

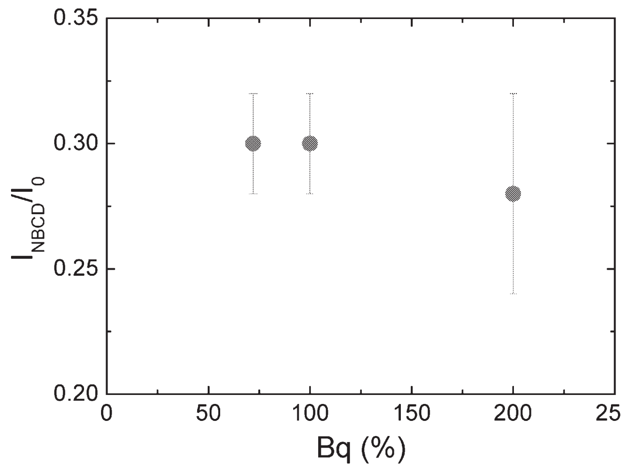

Fig.1 The NBCD coefficients v.s. Bq.

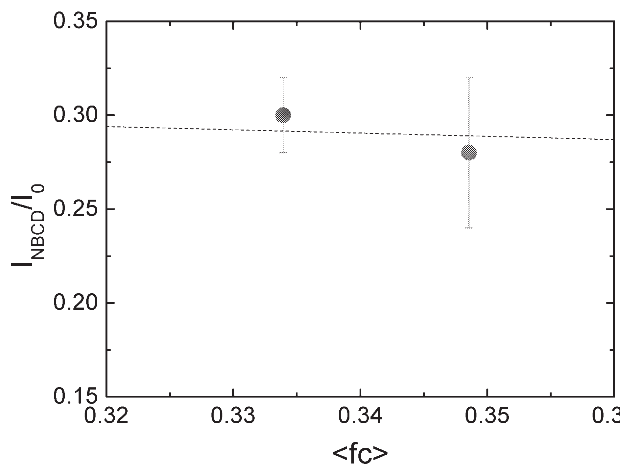

Fig.2 The NBCD coefficient v.s. the volume averaged fraction of toroidally circulating electrons. The dotted line shows the model given by eq.(1).