§7. Comprehensive Investigations on the Influence of Magnetic Topology, T_e and T_i Ratio and Collisionality on Thermal Transport in Strongly Ion-heated LHD Plasmas

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1. Introduction

Optimization of the magnetic topology has long been regarded as one of the issues of prime importance in fusion research, as it literally determines the fundamental plasma performances. On the other hand, much effort has been paid in the past decades to improve the prediction capability of confinement properties in burning plasmas, where extremely strong electron heating is anticipated by the energetic alpha particles (1). Therefore, it is by all means prerequisite to consider the multi-fluids model in practical experiments, with emphasis on the distinctive features, related to T_e and T_i ratio. It is well known that different modes of turbulence prevail, depending on the magnetic configuration and the T_e and T_i ranges. Thus, we have been intensively working on the comprehensive understandings of transport physics in a comparative manner between tokamaks and helical devices that do not accompany the plasma current formation. As a consequence of the extensive experiment in LHD performed for the last 3 years, where magnetic shear was modified by switching the tangential NBCD beams, it has been found that the local magnetic shear does not provide substantial influence on the thermal transport. Although the driven current exceeded 120kA in LHD in a broad range of density from 0.5 to $3.0\text{X}10^{19}\text{m}^{-3}$, and the magnetic shear crossed zero in many discharges, neither the gradient of T_e or T_i was modified more than a few percent under approximately constant heating power. Here, the magnetic axis was outward-shifted to avoid the influence of MHD. Indeed, the astonishing result, namely from a view of the tokamak experiment (2), has been recently obtained.

Accordingly, we have developed a hypothesis that magnetic shear could only suppress the growth rate of ion turbulence under reduced magnetic shear, and it is effective only in strongly ion-heated plasmas. In the 2010 LHD campaign, we have designed a series of extended experiments to repeat the similar discharge with strong ion heating with upgraded lower-energy (dominantly ion-heating) NB units.

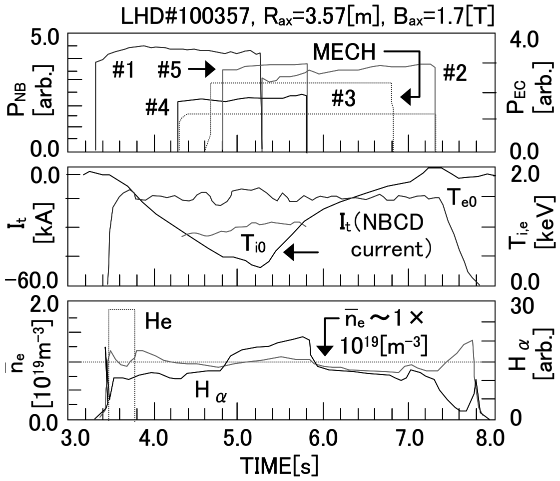

Fig. 1 Typical discharge waveforms for the magnetic shear modulation experiment under reduced T_{e0}/T_{i0} with NB#5.

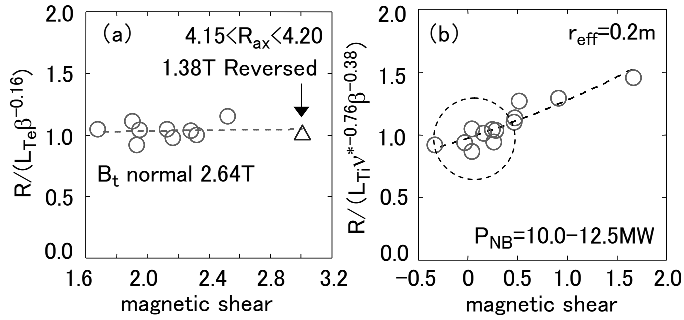

Fig. 2 Magnetic shear dependence of normalized R/L_T for (a) electrons and (b) ions (T_{e0}/T_{i0}<1.5).

2. Magnetic shear modulation under strong ion heating

The typical discharge waveforms are depicted in Fig. 1. Here, non-inductively driven current of approximately 60kA was sustained at $\bar{n}_e \sim 1\times10^{19}\text{m}^{-3}$ during the scans of magnetic shear and ion-heating fraction, and even $T_e/T_i<1$ was achieved in several discharges. In addition ECH power was modulated for the perturbative transport analysis.

The characteristic gradient lengths of T_e and T_i are shown in Fig. 2. R/L_{Te} is divided by the functional forms of $\beta^{-0.38}$ dependence, whilst R/L_{Ti} is divided by both the β and ν^* dependences to extract the contribution of magnetic shear. Although the ν^* dependence was not clear and for R/L_{Te}, R/L_{Ti} indicated the dependence on $\beta^{-0.38}\nu^{*-0.16}$ at around r_{eff} of 0.2 for ions and half the minor radius for electrons. It was documented hereby that R/L_{Te} does not show signs of magnetic shear dependence. T_e profile evolves in a stiff manner under the additional heating, however, changes of R/L_{Te} was subtle even in a region of T_e/T_i<1.5. Therefore, it could be deduced that electron transport is not influenced by the magnetic shear, regardless of the ranges of T_e/T_i. On the other hand, though not conclusive, R/L_{Ti} seems to increase with magnetic shear. The possible interplay of MHD might also be considered, though is it not evident in R/L_{Te}. In addition, the local minimum of R/L_{Ti} was not documented, which is claimed to exist near slightly negative region in the tokamak experiments. Therefore, it seems that the turbulence structure is fundamentally different between tokamaks and helical devices even under similar values of T_e/T_i, and the identification of the details calls for extensive research in future experiments.

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