§5. Comprehensive Investigations on the Influence of Intensive Electron Heating and Magnetic Topology on Anomalous Transport in Fusion Plasmas

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It is well known that optimization of the magnetic configuration is fundamental in magnetic confinement fusion, as it is directly relevant to plasma performances. After having an insight in the previous experimental campaign that local magnetic shear in LHD does not exhibit as much significance as in tokamaks[1], we have alternatively emphasized the possible contribution of T_e/T_i in the core region. The envisaged assertion is that LHD is dominantly electron-heated, whilst many of standard tokamaks are equipped with much lower-energy NBs, and predominant ion turbulence, as represented by ITG, is noticeably suppressed by the reduced magnetic shear. Namely, the degree to which the transport is improved might be influenced by the functional parameter, namely $f(s)g(T_e/T_i)$. Therefore, it is expected that an application of intensive ion heating under NCS i.e., negative central shear, could potentially reduce the anomalous fraction of transport in LHD. The significance of T_e/T_i has been pervasively recognized in the recent tokamak experiments, since high-performance discharges hitherto achieved in tokamaks may not prevail in burning plasmas where alpha particles strongly heat electrons. In fact, degradation of transport barrier as well as the loss of core density in the improved confinement regimes are reported elsewhere.

Consequently, the values of T_e/T_i , $\nu_{e,i}^*$ and local magnetic shear, $s=rd(\ln q)/dr$ or $2\pi rd(\ln\iota^{-1})/dr$ in the database accumulated in a series of dedicated experiment in LHD have been intensively analyzed, where the central magnetic shear was largely modified by the poloidal magnetic field induced by the NNB driven current of up to 120kA at approximately constant density of 1-2X10^{19}m^{-3}, using the beam switching technique[2]. Here, plasma column was outward-shifted to R_{ax}=3.7m, in order to eliminate the appearance of MHD instability.

In regard to the contribution of T_e/T_i on $R/T_{e,i}$, apparent relationship was not found, contrary to the expectations based on the previous LHD experimental results. Although a large scatter is present, a slight reduction of R/T_e against T_e/T_i was observed. Similar tendency was documented in the R/T_i vs. T_e/T_i plot. On the other hand, both R/T_e and R/T_i exhibit negative dependences on $\nu_e^*$and ν_i^*, respectively, which indicates that smaller collisionality is preferable to attain improved confinement, and thus an anomalous component persists in the core. The ranges of T_e/T_i herein discussed are 1.4-2.6, and $\nu_{e,i}^*$ of 0.2-1 for electrons and 0-7 for ions. The special location of the analysis was chosen to be around half minor radius, where the second derivative takes the local maximum values. When the dataset is limited to the range R/L_n>1.3, the scatter is somehow reduced for the electron branch, and an evidence of $\nu_{e,i}^*$ contributions was more clearly manifested. We have therefore, normalized the values of $R/T_{e,i}$ by $\nu_{e,i}^*$, respectively. In this case, the slight reduction of $R/T_{e,i}$ with T_e/T_i diminished both for ions and electrons.

As to the comparison between the LHD results and the tokamak database[3], we have analyzed and plotted the values of $R/T_{e,i}$ normalized by $R/T_{e,i}$ and $\nu_{e,i}^*$ against the local magnetic shear measured with the MSE diagnostic. As depicted in Fig. 1, values of $(R/T_{e,i})/\{f(\nu_{e,i}^*)g(T_e/T_i)\}$ increase towards the negative shear direction in tokamaks with the local minimum sitting around the zero shear region, both for ions and electrons. The scatter in the vertical direction for JET has not yet been resolved. However, it is obvious that the local shear does not influence the profile shape at all for LHD. The provisional conclusion is that not only s but also T_e/T_i does not make any contribution on the profile shape even at reasonably low density.

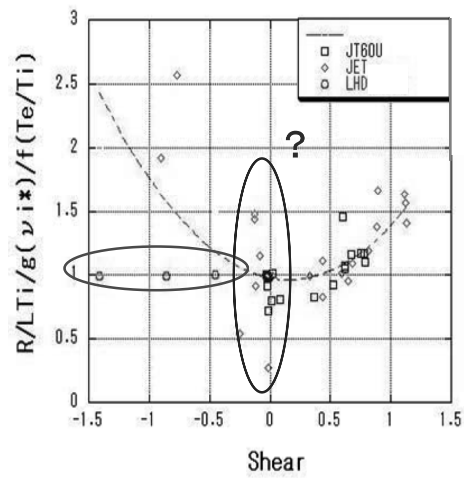

Fig. 1 Normalized T_e gradient plotted against local magnetic shear in LHD, JET and JT-60U.

1) Fukuda, T. et al.: Proc. th Fusion Energy Conf., 13-18 October, 2008, Geneva, EX/P5-11.
2) Fukuda, T. et al.: Proc. 36th EPS Conf., 29 June3-July, Sofia, 2009, P4.112.
3) Roach, C. M. et al: Nucl Fusion **48**(2008)125001.
4) Connor, J. W. et al.: Nucl. Fusion **44**(2004)R1.