§14. Comprehensive Investigations on Electron Transport in Toroidal Systems with Emphasis on Local Magnetic Geometry

Takai, R. (Osaka Univ.), Fukuda, T. (Osaka Univ.), Tamura, N., Ida, K., Inagaki, S. (Kyushu Univ.), Narita, E. (Osaka Univ.), Yoshinuma, M., Kasahara, H., Suzuki, C., Sakamoto, R., Sakamoto, Y., Urano, H., Ide, S. (JAEA)

1. Introduction

Optimization of the magnetic topology has long been considered as one of the issues of controversy 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]. It is well known that different modes of turbulence prevail, depending on the magnetic configurations. 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 dedicated experiments in LHD performed in the recent runs, 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 $3.0X10^{19}m^{-3}$, 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 obtained. On the other hand, it could be deduced that turbulence dominating the electron transport in LHD plasmas is not influenced by the local magnetic shear.

2. Ubiquity of the effect of local magnetic geometry

We have therefore revisited the international profile database PR08, comprised of H-mode discharges observed in 19 tokamaks[3], in order to reconfirm the influence of magnetic geometry on electron transport, namely the local poloidal field B_P, representing the zero-order physical quantity and magnetic shear s=rd(lnq)/dr, which is in turn the first order derivative quantity. They have both been transformed to nondimensional parameters, $|B_PR^{1.25}|$ and s/q[4], respectively and plotted against the electron temperature gradient either written as $|R/L_{Te}|$ or $|1/L_{Te}|$ in Figs. 1 and 2 below.

A noticeable dependence of $|R/L_{Te}|$ or on s/q was observed for AUG and T10. However, it does not seem to be related with $|B_PR^{1.25}|$, in spite of the strong I_p dependence in IPB98(y,2) global confinement scaling. The contribution of $|1/L_{Te}|$ was also confirmed both in the JET and DIII-D database. The spatial location of interest has been fixed at the local maximum of the B_P profile, as the result of regression showed much larger dispersion when the normalized radius of 0.5 was employed instead.

The dependence of $|R/L_{Te}|$ on internal inductance was obscure, and the results above indicate that locally determined differential quantity is more influential to the temperature gradient or thermal transport than zero-order or integrated numbers.

The electron thermal diffusivity was estimated using the linear stability code GS2[5], and it was plotted against the magnetic shear in Fig. 3. The Miller geometry[6] was hereby adopted for the model equilibrium. The effect flow shear has not herein been implemented. It is obvious that an increase of magnetic shear reduces electron thermal diffusivity at various values of R/L_{Ti}, and it corroborates the results of regression analysis shown in Figs. 1 and 2. Though the values of magnetic shear reside well in the positive region, it is directly relevant to the s-alpha relationship i.e. MHD features, pervasively recognized in the tokamak experiments. However, it was not possible to document the relevant characteristics in the previous experiments in LHD.

(1) Stix, T.H.: Plasma Phys. **14** (1972) 367.

(2) Connor, J.W. et al.: Nucl. Fusion **44** (2004) R1-R49; Fujita, T et al.: Plasma Phys. Control. Fusion **46**(2004)A35; Maget, P. et al., Nucl. Fusion **39** (1999) 949; Newman, D. E. et al.: Phys. Plasmas **5** (1998) 938.

(3) Roach, C.M. et al.: Nucl Fusion **48** (2008) 125001.

(4) Hoang, G.T. et al.: Phys. Rev. Lett. **87** (2001) 125001.

(5) Kotschenreuther, M. et al.:Comp. Phys. Comm. **88** (1995) 128.

(6) Miller, R.L. et al.:Phys. Plasmas **5** (1998) 973.

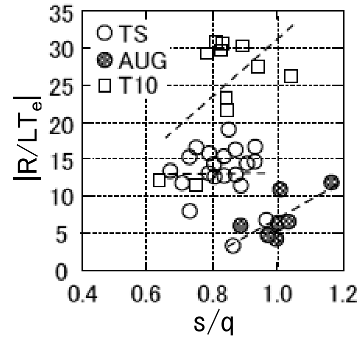

Fig. 1 Dependence of normalized electron temperature gradient on local magnetic shear in TS, AUG and T10.

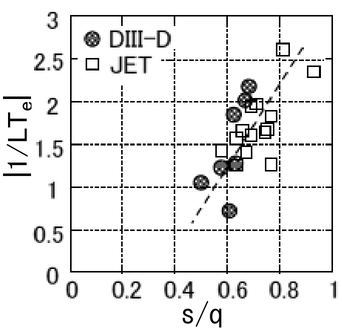

Fig. 2 Dependence of electron temperature gradient scale length on local magnetic shear in DIII-D and JET

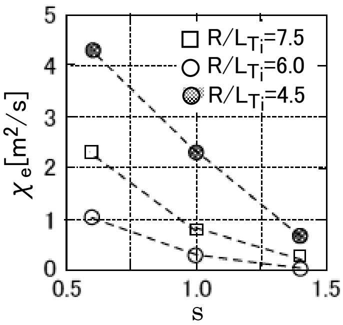

Fig. 3 Dependence of electron thermal diffusivity on local magnetic shear, estimated using the linear stability code GS2.