§28. Trial of Experimental Confirmation of Geometrical Effects on Transport Properties Related with MHD Instabilities

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In the typical LHD low-beta (β) discharges, global and local transport properties are described by the so-called ISS04 empirical scaling, which has the similar dependence of dimensionless plasma parameters to the so-called gyro-reduced Bohm (GB) anomalous transport model[1,2]. On the other hand, in the LHD high- β discharges, the normalized local thermal conductivities degrade as the beta decreases, that is, the normalized thermal conductivity is almost proportional to β^1. The behavior is similar to an anomalous transport model driven by electro-magnetic instability turbulence. In addition, the level of the degradation depends on the minor radial location, that is, the level in peripheral region is larger than that in the core. Figure 1(a) shows the radial dependence of the typical geometric factors, the rotational transform (ι) and the magnetic hill parameter ($V''=dV^2/d\rho^2$) in a typical LHD configuration, where the shear of ι is week in the core and is strong in the peripheral, and the magnetic hill parameter is small (sometimes negative; well) in the core and is large in the peripheral. The resistive interchange is more unstable in the low shear of ι and the large magnetic hill parameters. The characteristics of the local thermal conductivity are quite consistent with an anomalous transport model driven by the resistive interchange instability turbulence[3]. Figure 1(b) shows the ι profile of Heliotron J (H-J). In H-J, the shear of ι is week in the whole region, where the magnetic hill parameter is small. Then the comparative analysis between the experimental transport properties of LHD and H-J would lead to the confirmation of the geometrical effects on the properties related with MHD instabilities.

In order to analyze the transport property in H-J, we are improving a tool based on the TASK4LHD 1-dimensional (1D) transport code[4], which calculates the NBI heating power by a Monte Caro code, and the MHD equilibrium, which is used in the LHD transport analysis. The main improving points are the follows; (1) MHD equilibrium is calculated based on the HINT code, which is an equilibrium solver based on the real coordinates. (2) Distribution of the plasma densities and temperatures in the real space, which is necessary to evaluate the NBI heating profile, are evaluated by using VMEC coordinates. In LHD, the MHD equilibrium is evaluated by the VMEC free-boundary version. In H-J, the way is not applicable because the plasma boundary shape is too complicated for the VMEC free-boundary code algorism to represent it. Then HINT code is used. In the orbit calculation in LHD, which is necessary to evaluate the NBI heating power, the Boozer coordinates are used. However, in H-J, the excursion of the magnetic axis is too large that the accuracy of the mapping between the real coordinates and the Boozer coordinates is bad. The mapping between the real coordinates and the VMEC coordinates is used because the toroidal angle in the VMEC is exactly same with that in the real coordinates. Here it should be noted that the MHD equilibrium mapping data in the VMEC coordinates is calculated by the VMEC fix-boundary version to be consistent with the plasma boundary calculated by HINT code.

Now the transport analysis is being applied for the discharges with ECH and NBI, where the ion and the electron temperatures and the electron density are shown in Fig.2[5]. The electron temperature and density profiles are measured by gathering 30 discharges with the same experimental conditions.

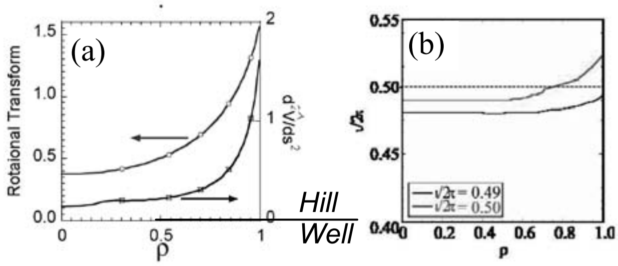

Fig. 1. Radial dependence of the typical geometric factor, (a) ι and V"= in LHD. ι in H-J.

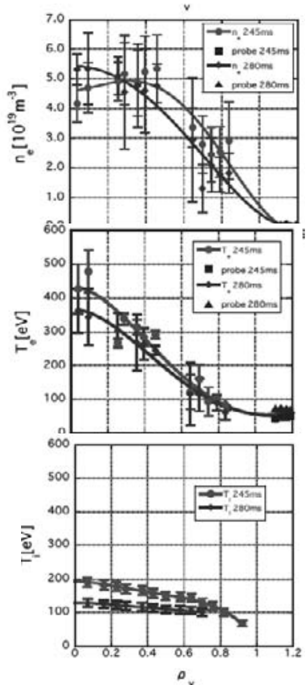

Fig. 2.Radial profile of the electron and the ion temperatures and the electron density in a typical H-J discharge with ECH and NBI.

1) H.Yamada et al. Nucl. Fusion 45,1684 (2005).
2) H.Funaba et al., Plasma Fus. Res. 8, 022 (2008).
3) K.Y. Watanabe et al., Phys. Plasma 18 (2011) 056119.
4) R.Seki et al., Plasma Fusion Res. 6, 2402081 (2011).
5) H.Fukushima, in Proc. of 29th JSPF annual meeting, Nov. 2011, Fukuoka(Japan).