§16. Effects of MHD Equilibrium Characteristics on the Transport Properties in Helical Plasmas

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On the LHD-like helical plasmas, the MHD equilibrium properties, especially in the core region, strongly changes depending on beta value because their Shafranov shift is fairly large due to the small rotational transform. In addition, the bootstrap current would affect the equilibrium properties because the configuration is not optimized to reduce the current. For example, in discharges with super high density in the core[1)], the profile of which is much peaked, the property of the equilibrium is much deferent from that in the low beta discharges. In addition, the state is transient because it is produced by the pellet injection. Our purpose of the present study is the construction of the prediction models with good accuracy, which is improved through the comparative analysis between the transport calculation results taking the time-evolution of the equilibrium into account and the experimental ones. In order to complete it, we should develop the so-called 2.0-dimension transport code consistent with time evolution of the equilibrium.

At first, we estimate the effects of the time-evolution of the equilibrium on the transport properties in the so-called SCD (super-core-density) plasma in LHD as an example. The time evolution of the electron density obeyed the following equation when we take the time-evolution of the magnetic configuration into account,

$$\frac{\partial}{\partial t}(V' n_e) = -\frac{\partial}{\partial s}\left(V'\left\langle|\nabla s|^2\right\rangle\left(-D\frac{\partial n_e}{\partial s}\right)\right)$$

Here V' is the normalized toroidal magnetic flux. D is the diffusion coefficient. The geometric factors, V' and $\left\langle|\nabla s|^2\right\rangle$ are proportional to 1 and s in the case that the magnetic surfaces are the concentric circles and the magnetic field strength is constant. On the contrary, their dependence much changes in the case that the surfaces are not the concentric circles and the field strength is not constant. Figure 1 shows (a) V' and (b) $\left\langle|\nabla s|^2\right\rangle$ as the function of the minor radius, $\left(\sqrt{s}\right)^2$. Both of them are quite different from those in the constant field and the concentric circle surfaces, where V' and $\left\langle|\nabla s|^2\right\rangle$ are proportional to 1 and $\left(\sqrt{s}\right)^2$.

In addition, according to the thermal transport analysis in high-beta LHD discharges, the thermal conductivity normalized by the gyro-reduced Bohm model at the peripheral region degrades as the beta increases. In the peripheral region of LHD, the configuration is still in the magnetic hill, and the beta dependence of the normalized thermal conductivity is quite consistent with an anomalous transport model based on the g-mode turbulence [gmt][2,3)]. The transport coefficients based on the gmt model strongly depend on the characteristic of the geometric parameters (the height/depth of the magnetic hill/well, rotational transform and its shear and so on). Figure 2 shows the time evolution of the electron density and the temperature profiles calculated by a transport code taking the time evolution of the equilibrium into account, where the plasma parameters for the typical SDC discharges shown in ref 1 are used as the initial conditions of the transport calculation. Here we assume that the plasmas consist of the one ion species and the electron. As the particle and thermal transport models, we take the neoclassical and the anomalous ones based on the gmt model. As the heating power profile, the typical one which is expected in NBI is used. It should be noted that that is not consistent with the time evolving plasma parameters. The calculation result reproduces a behavior of the electron density profile that its profile is peaking, but does not the detail of the time evolution of the plasma parameters yet, for example, the location of the steepest density gradient. The model improvement based on the comparative analysis is the main future subject.

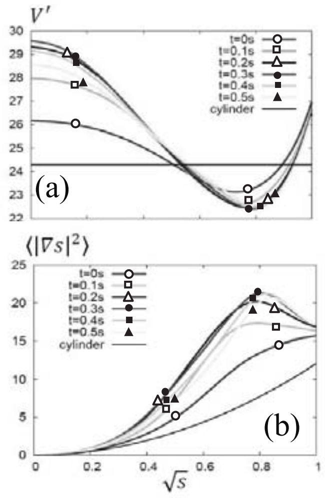

Fig. 1. The time evolution of the geometric profiles, (a) V' and (b) $\left\langle|\nabla s|^2\right\rangle$ during a typical SDC discharge.

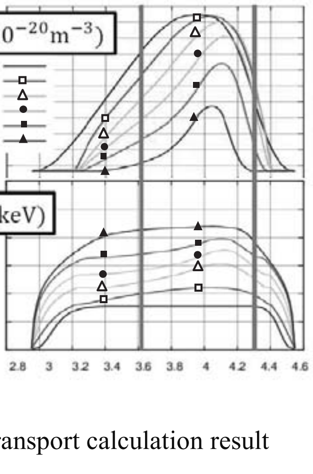

Fig. 2. A transport calculation result

1) R. Sakamoto et al., Nucl. Fusion 49 (2009) 085002.
2) B.A. Carreas et al, Phys. Fluid B1 (1989) 1011.
3) K.Y. Watanabe et al., Phys. Plasma 18 (2011) 056119.