## §14. Prediction of Collisionless High-Beta Heliotron Plasmas Based on LHD Experiment Scaling and Model

Seki, R., Sato, M., Watanabe, K.Y., Funaba, H., Suzuki, Y., Sakakibara, S., Yokoyama, M.,
Fukuyama, A. (Dept. Nucl. Eng., Kyoto Univ.),
Murakami, S. (Dept. Nucl. Eng., Kyoto Univ.), Nakajima, N.

In the LHD experiment to extend the beta regime to the reactor-relevant high-beta plasmas with $\langle\beta\rangle\sim5\%$, the discharges are in quasi-steady maintained without disruptive phenomena [1]. The thermal conductivity for many LHD high beta discharges is analyzed on the basis of the power balance, and the local transport properties are summarized as following.

(1) The local thermal transport properties in the low beta regimes have the similar dependence on the non-dimensional parameters with the ISS04 global energy confinement scaling when the geometric factor is introduced [2].

(2) The transport properties in the high-beta regime have the similar dependence on both the non-dimensional parameters and the configuration parameters with a resistive interchange MHD instability turbulence (GMT) driving anomalous transport model [3].

The above knowledge enables us to propose the local transport model, which gives a more accurate prediction of the plasma performance compared with the early researches in the helical plasmas, as shown in the following.

$$\chi_s(\rho)=\chi_{CHs}(\rho) + \chi_{SHs}(\rho) + c_{1s}*\chi_{ISS04s}(\rho) + c_{2s}*\chi_{GMTs}(\rho).$$

Here 's' denotes the particle species. $\chi_{ISS04}$ and $\chi_{GMT}$ denote anomalous thermal conductivities of the local ISS04 model [2] and the GMT type [4], respectively. $\chi_{CHs}$ and $\chi_{SHs}$ are the axisym metric part and the non-axisymmetric part of the neoclassical transport. $c_{1s}$ and $c_{2s}$ are the constant with the order of unity as to well produce the experimental temperature profiles. In the typical LHD configuration, most of the above particles can re-enter in the region of the closed flux surfaces when they do not experience the collision, which is called "re-entering fast ion". The heating power profile is evaluated taking the re-entering fast ion effect into account, by the real coordinate Monte-Carlo code, MORH [5]. Figure 1 shows the reproduction results for the LHD high-beta discharge maintained by the tangential-NBI with 0.43T and $\langle\beta\rangle\sim4.7\%$. The calculation is done by a hierarch-integrated code TASK3D [6] assuming that densities do not change. Figure 1 (a) shows the experiment electron temperature and the reproduced electron and ion temperatures. Although there is a little deference, the proposed model almost reproduces the experiment temperature.

To obtain a more accurate extrapolation for the reactor, we need to extend the LHD operational regime to the low-collisional regime in addition to the high-beta regime. We investigate an optimized operational condition in the higher field regime, for example $B_0$=0.9T, than the present high-beta discharge because the increase of $B_0$ is much effective to increase the magnetic Reynolds number, S. Figure 2 shows the expected operation regime in the $\langle\beta\rangle$ and the S at ρ=0.5 diagram. The hatched region corresponds to the operational condition. The green triangle corresponds to the Fig. 1 discharge. The blue close symbols denote the predicted operational regime in 0.9 T operations with 15 MW port-through power of the $NBI_{//}$, which corresponds to the maximum heating power in the hatched region. Here, the averaged density changes, and the squares and the circles denote the flat and peaked density cases, respectively. For the same average density, the flat density profile is favorable to push up the S. It should be noted that in the hatched region with $B_0$=0.43T, the typical density profile is flat. From Fig. 2, by the increase of $B_0$ from 0.43T to 0.9T, the achievable $\langle\beta\rangle$ decreases from 4.7% to 3.5%, but the S increases 10 times larger at $\langle\beta\rangle\sim3.5\%$. Next we will investigate the $NBI_\perp$ impact with and without the re-entering effect. When the re-entering fast ions are taken into account, the effective heating power of the $NBI_\perp$ is about 2.5 times as large as that without the re-entering effect, where the heating power profile by the available LHD port-through $NBI_\perp$ powers, 12MW, in $\langle\beta\rangle\sim3.5\%$ case are shown. In the expected operation regime by the addition of the $NBI_\perp$ with re-entering effect, which are shown by red close symbols in the Fig. 2, the achievable $\langle\beta\rangle$ increases by about 0.2 %, while the S rarely changes.

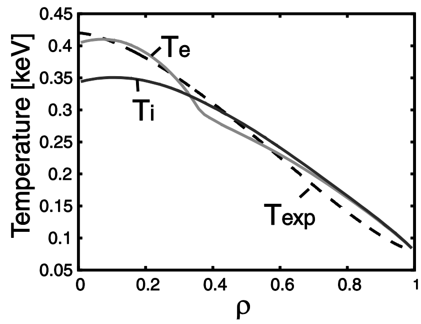


Fig. 1 Minor radial profiles of the reproduced electron and ion temperatures.

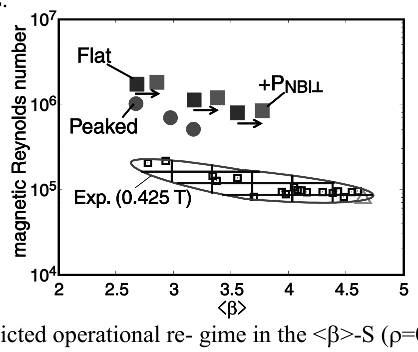


Fig. 2 Predicted operational re- gime in the <β>-S (ρ=0.5) diagram.

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