§6. Predictions of High-Ti Deuterium Experiment Plasma in LHD

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The deuterium experiment project from 2017 is planned in LHD, where the deuterium NBI heating beams with the power more than 30MW are injected into the deuterium plasma. Principal objects of this project are to clarify the isotope effect on the heat and particle transport in the helical plasma and to study energetic particle confinement in a helical magnetic configuration measuring triton burn-up neutrons.

We have developed an integrated transport simulation code, TASK3D, and applied to the high ion temperature plasma of LHD[1]. In this paper, we predict the plasma performance of the deuterium experiment plasma in LHD by applying the TASK3D and GNET[2, 3] codes.

We perform the integrated transport simulation of deuterium plasma by TASK3D code. A typical density profile is assumed as $n_s(r/a) = n_{s0}\{1-(r/a)^8\}$ where s denotes species of plasma. We assume two central density cases; $n_{e0} = 2.0$ and 3.0×10^{19} m^{-3}, and the deuterium-hydrogen density ratio as $n_D/(n_D + n_H) = 0.8$.

We evaluate the heat deposition profiles for the multi-ion species plasma (e, H, He, C) by using the multi-ion version of GNET[3], which can treat the D and H ion heatings precisely. Three tangential NBI heating (#1-3) with the beam energy $E_b = 180$keV and the heating power $P_{tNBI} = 14$MW, and two perpendicular NBI heating (#4 and 5) with $E_b = 60-80$keV and $P_{pNBI} = 18$MW are injected to the deuterium plasma of LHD. Figure 1-(top) shows the heat deposition profiles of the electron, deuterium and hydrogen ions. We can see peaked heating profiles of the electron and deuterium ion heating.

One-dimensional (1-D) diffusive heat transport equation with multi-ion species (H, He, C) is solved using the heat deposition profiles by GNET. We assume that the heat transport consists of the neoclassical and turbulent transports. The neoclassical transport database, DGN/LHD, evaluates the neoclassical heat transport for all species, and the radial electric field is determined by the ambipolar condition of neoclassical electron and ion fluxes.

In our previous studies, we have assumed the gyro-Bohm model for the electron heat diffusion and the gyro-Bohm+grad-T_i model, χ_{gBTi}, for the ion one as the turbulent transport model for the hydrogen plasma[1]. However, it is necessary to consider the isotope effect in the deuterium plasma case. To solve this problem we have performed the H/He experiment in the 2014 campaign of LHD. We have varied the H-He ratio, $\xi_H = n_H/(n_H + n_{He})$, keeping the electron density profile. The heat transport simulations are performed to H-He plasma by TASK3D and the heat deposition was evaluated by the multi-ion version of GNET. It is found that the ion temperature increases as ξ_H decreases while the electron temperature shows almost no change. We consider that this ion temperature increment is due to the reduction of turbulent transport by the isotope effect. Thus, we assume a turbulent transport model with an improvement factor depending on the effective mass number $A_{eff} = \sum_i (M_i/Z_i)n_i/n_e$ to the χ_{gBTi} model as $\chi_i^{turbulent} = \chi_{gBTi} \times \exp[-k_A(A_{eff} - c_A)]$ with $k_A = 2.0$ and $c_A = 1.4$.

Figure 1-(bottom) shows the deuterium ion temperatures in the deuterium experiment plasma of LHD with and without the isotope effect on the turbulent transport assuming the A_{eff} depending model. It is found that the deuterium ion temperature reaches more than 6 keV with the isotope effect in the deuterium experiment plasma. On the other hand, the ion temperature reaches about 5 keV if we assume a pure hydrogen plasma. This result indicates that we will obtain about 20% higher ion temperature than that of the hydrogen plasma in the deuterium experiment of LHD if we assume an isotope effect on the turbulent transport based on the He/H experiment results.

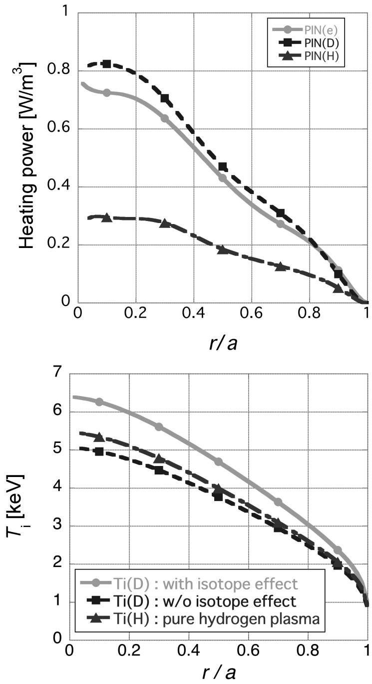

Fig. 1: *Radial profiles of the NBI heat depositions (top) and ion temperatures (bottom) in the deuterium experiment plasma with* $n_{e0} = 2.0 \times 10^{19}$ m^{-3} *and* $n_D/(n_H + n_D) = 0.8$.

1) S. Murakami et al., Plasma Phys. Control. Fusion **57**, 054009 (2015).
2) S. Murakami et al., Nuclear Fusion **46**, S425 (2006).
3) H. Yamaguchi and S. Murakami, Nucl. Fusion **56** (2016) 026003.