§27. The First Results of Hydrogen Isotope Effects on Particle Transport in Heliotron-J

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The study of the isotope effect on a particle transport is important issues for the prediction of the future D-T fusion reactor. In ASDEX tokamak, D_{mod} of the deuterium dominant plasma is smaller than that of the hydrogen one in $\bar{n}_e = 1 \times 10^{19} \sim 5 \times 10^{19}$ m^{-3} with Ohmic heating [1]. In CHS helical device with NBI heating, the lower D_{mod} was reported in the deuterium dominant plasma than in the hydrogen one in $\bar{n}_e < 2.5 \times 10^{19}$ m^{-3}, while no clear difference was observed in $\bar{n}_e > 2.5 \times 10^{19}$ m^{-3} [2]. However, the experimental data of isotope effects on particle transports are very limited. In this paper, we report the first result of isotope effect on the particle transport of Heliotron J. The experiments were performed in ECRH heated plasmas and magnetic configuration was standard configuration in Heliotron J

Figure 1 shows comparison of the decay of the density after turning off of the gas puffing. The decay time, which is defined as an effective particle confinement time (τ_p^*), is clearly longer in the deuterium dominant plasma than in the hydrogen dominant plasma. This suggest better particle confinement in the deuterium dominant plasma, however, τ_p^* is also affected by the wall fueling due to the recycling. Thus, in order to distinguish transport and wall recycling effects, density modulation experiments were performed. The modulation phase and amplitude ratio were measured by the microwave interferometer (tangent position ρ_t=0.05) and far infrared laser interferometer [3] (ρ_t =0.3). Then, numerical fitting analysis were performed to determine diffusion coefficient (D_{mod0}) and convection velocity $V_{\mathrm{mod}}(r)$ [4]. The spatially constant D_{mod0} and $V_{\mathrm{mod}}(r)=r/aV_{\mathrm{mod0}}$, where V_{mod0} is convection velocity at plasma boundary and a is plasma boundary radius, were used for the analysis. Since the available interferometer channel is only two, three different modulation frequency, which were 50, 100 and 125Hz, were applied in order to increase fitting constraint. As shown in Fig.2, different amplitude ratio and phase were observed in the deuterium and the hydrogen dominant plasma.

Figure 3 is the comparison of D_{mod0} and V_{mod0}. As shown in Fig.3, D_{mod0} is lower in the deuterium dominant plasma, while the difference of the V_{mod0} is within the error bar. It should be noted that the is V_{mod0} inwardly directed. The density profile measured by the Thomson scattering is hollowed. This indicates there exists outwardly directed convection velocity in equilibrium state (V_{eq}). The different direction of V_{mod0} and V_{eq} suggests there exists difference of the transport coefficients from transient analysis and equilibrium state. This is possibly due to the non linearity between density and particle flux[5]. The global particle confinement is estimated by $\tau_p = a^2/5.76D_{mod}$ [2]. As shown in table.1, τ_p and τ_p^* are 20 % and 30% longer in the deuterium dominant plasma than in the hydrogen dominant plasma respectively. The τ_p is 3.7 and 3.4 times longer than τ_p^* in the deuterium and hydrogen dominant plasma respectively. This suggests that particle confinement is better and recycling is stronger in the deuterium dominant plasma than in the hydrogen dominant plasma.

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2) Tanaka. K., et al, Plasma Phys. Control. Fusion 58, 5 (2016)
3) Ohtani. Y., et al., Plasma Fusion Res. 10, 1402091 (2015)
4) Ohtani. Y., et al.,J. Instrum. **11**, C02035 (2016)
5) N. J. Lopes Cardozo, Plasma Phys. Control. Fusion **37** 799 (1995)

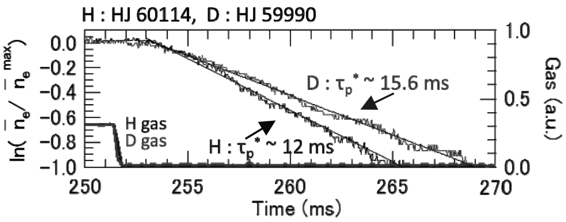

Fig. 1. The time development of $\ln(\bar{n}_e/\bar{n}_e^{\max})$ and gas puff signal in the density decay experiment. Black lines are fitted lines to evaluate τ_p^*.

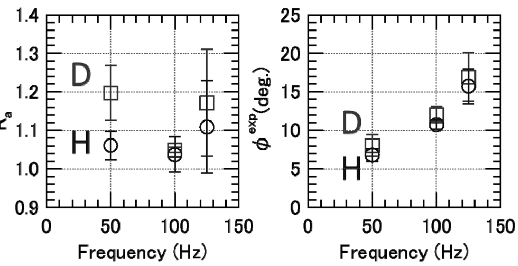

Fig. 2. (a) Amplitude ratio and (b) phase difference from density modulation experiment. Deuterium(□) and Hydrogen(○) dominant plasma

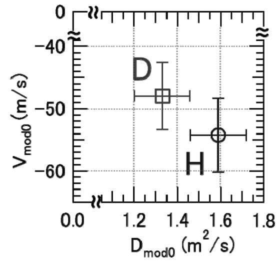

Fig. 3. Optimal D_{mod} and V_{mod} for deuterium and hydrogen dominant plasmas.

Table.1. Comparison of τ_p^* and τ_p

	Deuterium	Hydrogen
τ_p (ms)	15.62±0.07	11.98±0.05
τ_p^* (ms)	4.23±0.41	3.54±0.29