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Isotope Effects on Particle and Energy transport in CHS

CHSにおける粒子および熱輸送の同位体効果

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The hydrogen isotope effects on particle and energy transport is studied in Compact Helical System (CHS) at NIFS Higashiyama cite of Nagoya-city in 1998-1999. The fueling ratio (D/(H+D)) was scanned from 10-80% changing fueling gas. Heating was hydrogen NBI. Lower particle diffusivity and more inwardly directed core particle pinch were found in deuterium dominant plasma than in hydrogen dominant plasma in in low density region (line averaged density < 2x10^{19}m^{-3}), while no difference was found in higher density region. The global energy confinement in low density region is 20% better in deuterium dominant plasma than in hydrogen dominant plasma.
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1. Introduction

Isotope effects on transport between hydrogen (H), deuterium (D) and tritium (T) are important to predict the performance of fusion reactor. In tokamak, different characteristics of isotope effects between hydrogen and deuterium are reported. In deuterium plasma, H mode threshold power becomes lower and electron and ion thermal diffusivities becomes lower as well[1]. While in helical plasmas, improvement of the transport in deuterium plasma is very modest. In ECRH heating plasma of W-7AS, the stored energy higher by 20% in D is reported at the same density regime[2]. However, due to the limit of the data set in helical devices, isotope effects on transport have not yet been clearly shown from experiment. Comparison experiments in D and H plasmas were done in Compact Helical System (CHS) at National Institute for Fusion Science in 1998-1999. The data are mined and analyzed for isotope effects study in helical devices. This study also aims to predict the transport characteristics of deuterium plasma in the Large Helical Device (LHD) planned from 2016.

2. Comparison of Global Transport

Fig.1 shows difference of time evolution in D dominant and H dominant plasma. Toroidal magnetic field was 0.9 T, magnetic axis 92.1cm, and the plasma was attached to a wall of vacuum vessel on the inboard side. After production of 50.4GHz ECRH, plasma is heated by 200kW neutral beam injection. Injection beam species is hydrogen. Then, H and D gas for plasma production were switched in the series of shots. As shown in Fig.1 (a-2) and (b-2), global energy confinement time (τ_E) increases only by about 20% in D dominant plasma. This enhancement almost disappears when normalized by ISS95 scaling. But clear difference of density decay time is observed.

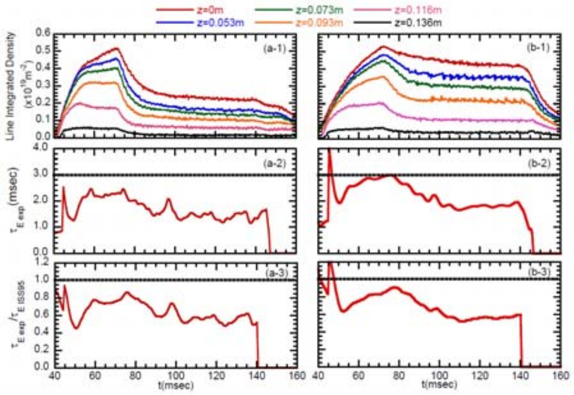

Fig. 1 Comparison of discharge in H dominant (a-1,2,3) and D dominant (b-1,2,3) plasma. (a-1) (b-1) line integrated density, (a-2) (b-2) global energy confinement time and (a-3) (b-3)H factor. Z are vertical position of horizontally viewing interferometer chord

The decay time is determined by particle confinement and fuelling. Gas puff was switched off at 70ms, but the wall recycling continues fuelling. The difference of the decay time is clearer at the chord closer to the center (at smaller z), where effects of the wall recycling are smaller. This suggests difference close to plasma center is due to difference of particle transport rather than difference of the recycling. However, the decay time of central chord (z=0) is too much. It is 20ms in H dominant and 120ms in D dominant plasma. Factor six difference is unlikely to be caused by the difference of the particle transport only. It is likely that higher recycling rate also causes longer decay time in D dominant plasma.

3. Analysis of Particle Transport and Discussion

In order to study quantitative particle transport, particle diffusivity (D_{mod}) and convection velocity (V_{mod}) were estimated from density modulation experiments. Density was modulated at 100Hz and background density was ramped up gradually in time to study density dependence. Fueling ratio (D/(H+D) was scanned changing fueling gas. From the comparison of Hα and Dα intensity, it varied from 10-80%. Figure 2 shows radial density profiles from interferometer data. Profiles are calculated every 1msec and accumulated for analysis time window. As shown in Fig.2, difference of density profiles is seen in low density regime, but almost no difference is seen in high density regime. Figure 3 shows density dependence of D_{mod} and V_{mod}. Horizontal error bar indicates the density regime of analysis time window. Vertical error bar indicates fitting error of the analysis. The difference of estimated D_{mod} and V_{mod} is seen at $n_{e\_bar}<2x10^{19}m^{-3}$, and almost no difference is seen at $n_{e\_bar}>2x10^{19}m^{-3}$ as well as density profiles in Fig.2. Diffusion coefficients show negative density dependence as shown in Fig.3 (a). This is similar to the negative collisionality dependence observed in LHD[3]. At $n_{e\_bar}<2x10^{19}m^{-3}$, diffusion coefficients becomes clearly lower in D dominant plasma than in H dominant plasma indicating improvement of particle transport. The modeled D_{mod} is spatially constant, but, modulation amplitude is mainly localized at ρ>0.5. Thus, this improvement mainly comes from ρ>0.5. Figure 1 suggests better improvements inner region, but, in this analysis, it is difficult to state about difference of the diffusiveities at ρ <0.5. Convection velocity at ρ =0.5 increases outwardly at $n_{e\_bar}<2x10^{19}m^{-3}$ in H dominant plasma. This tendency is also similar to LHD results, where core convection increases outwardly with decrease of collisionality at

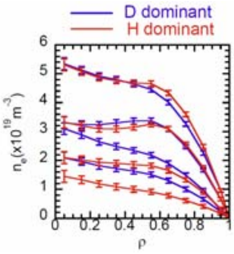

Fig.2 Density profiles in H and D dominant plasma

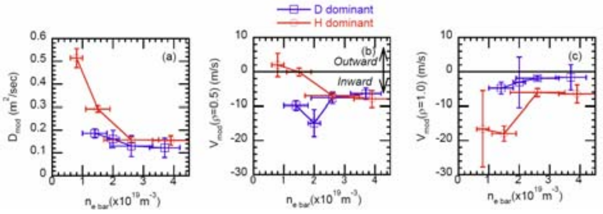

Fig.3 Density dependence of (a) D and (b),(c) V in H and D dominant plasma

magnetic axis (R_{ax}) is outer than 3.6m [3]. This can be explained by the outward convection due to neoclassical thermo diffusion. While in D dominant plasma, V_{mod} (ρ=0.5) at $n_{e\_bar}<2x10^{19}m^{-3}$ is more inwardly directed than the one at $n_{e\_bar}>2x10^{19}m^{-3}$. In LHD, such tendency was seen at very inwardly shifted configuration (R_{ax}=3.5m), where magnetic hill is dominant. However, in this experiment, magnetic property is same in H and D dominant plasma. The mechanism of density peaking observed in D dominant plasma of CHS is different from ones in H plasma in LHD at R_{ax}=3.5m. Neoclassical effects does not cause density peaking. In D dominant plasma, anomalous effects can cause density peaking.

From results obtained, the following are concluded. Isotope effects of particle transport in CHS is seen only in low density region at $n_{e\_bar}<2x10^{19}m^{-3}$. In this region, diffusion becomes lower and V_{mod} (ρ=0.5) becomes more inwardly directed. This suggests that with same fueling, density becomes higher in D dominant plasma, and density profiles becomes more peaked in low density region. The peaked density profile might be favorable to increase beam deposition in central region, which is realized in high T_i discharge in LHD. Improvement of the confinement due to larger generation of zonal flow in D plasma is theoretically expected[4]. Such phenomena is more evident low collisionality regime due to smaller damping of zonal flow. This is one of possible interpretation of obtained results.

References

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