SIMULATION OF DEUTERIUM-TRITIUM ISOTOPE EFFECTS ON THE DIVERTOR TARGET HEAT FLUX DENSITY IN CFEDR

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1. MAIN TEXT FORMAT

CFEDR deuterium-tritium (D-T) discharge is an important step for chinese nuclear fusion energy. With the fusion power of several gigawatts in CFEDR, the divertor target will face significant challenges in heat flux deposition (q_t)[1]. However, the D-T isotope effect can cause differences in transport and collisions of plasma in the scrape-off layer and divertor, which could affect neutral radiation in divertor region, as well as heat flux decay length (λ_q), thereby affecting qt[2][3]. In this work, we investigate the isotope effects of q_t on CFEDR using SOLPS-ITER modeling, and the simulation results agree with previous D-T simulation from the JET-ILW[4][5]. As shown in Fig. 1, the midplane pedestal density in the equal-proportion D-T discharge (Γ_D:Γ_T = 1:1) is higher than that in the pure deuterium (D) discharge, with a smoother T_e gradient near the separatrix and a larger λ_q. In D-T discharge conditions, both the T_e and q_t are slightly lower compared to the D discharge. In divertor region, D and T exhibit similar overall distribution trends. However, distinct differences are observed near the target: both T+ and T show stronger accumulation close to the target compared to D^+ and D, while the n_D and n_{D+} are higher in regions farther from the target. Both deuterium D and T charge exchange (CX) reduces the temperature of neutral particles, leading to their accumulation near the target. This results in an increase in neutral particle density and enhances both momentum and energy losses of the plasma in the divertor region. Furthermore, simulations of D-T discharge with different injection ratios (i.e. Γ_D:Γ_T = 1:1, 10:1, 100:1) were conducted to analyze their impact on divertor plasma and neutral particle distributions (see Fig. 2). The results indicate that as the T fraction decreases, the proportion of T atoms in both the target and PFR diminishes. Concurrently, the accumulation of T near the target and the neutral pressure in divertor region are decreased, as well as the ionization and collision rates of T near the target are reduced, resulting in T_e and q_t increase. For future fusion devices, injecting impurity gases is essential to reduce the heat flux density at the target[6]. In D-T discharge conditions, the thermal and frictional forces acting on impurity ions differ from those in pure D scenarios, altering impurity distribution and energy radiation. Therefore, we will focus on the impact of isotope effects on impurity radiation under gas injection conditions, aiming to further elucidate the mechanism by which isotope effects influence the q_t.

2. FIGURES

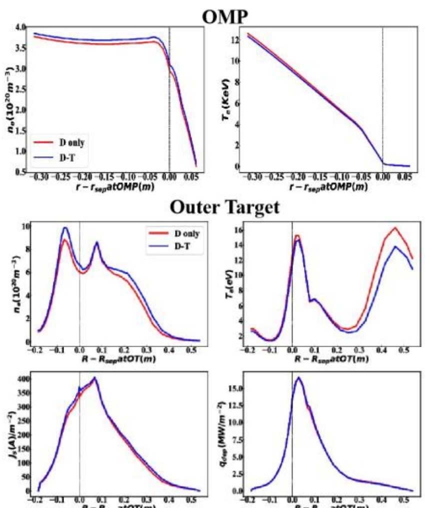

Figure 1. The plasma profile of mid-plane and outer target in pure D and D-T discharge condition.

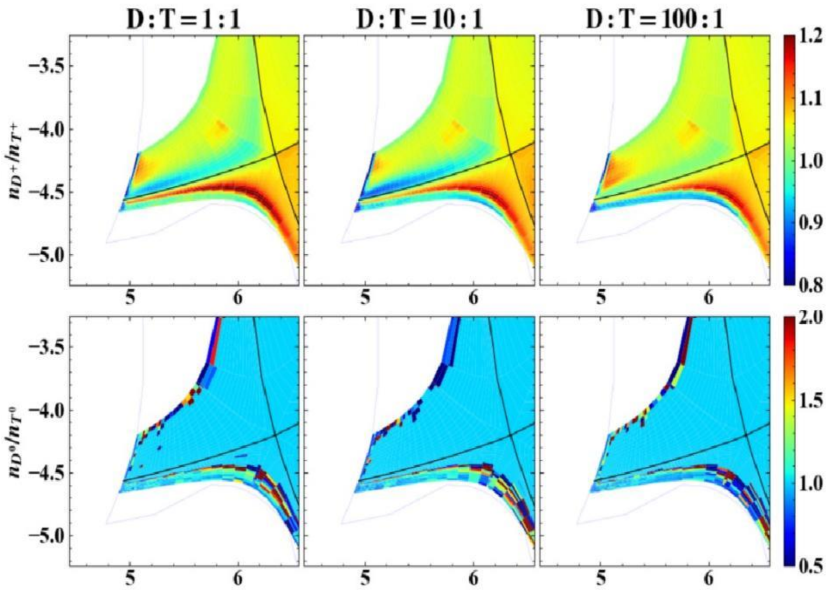

Figure 2. The ratio of D and T distribution in divertor region with different injection ratios (i.e., Γ_D:Γ_T = 1:1, 10:1, 100:1).

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REFERENCES

[1] Si H, Rui Ding1, Ilya Senichenkov et al, SOLPS-ITER simulations of high power exhaust for CFETR divertor with full drifts, *Nucl. Fusion* **62** (2021) 026031

[2] Faitsch M, I. Balboa, P. Lomas et al, Divertor power load investigations with deuterium and tritium in type-I ELMy H-mode plasmas in JET with the ITER-like wall, *Nucl. Fusion* **63** (2023) 112013

[3] Sun H J, S.A. Silburn, I.S. Carvalho et al, The broadening of SOL profiles in JET tritium plasma and its impact on machine operation, *Nucl. Fusion* **63** (2023) 016021

[4] Kaveeva E, I. Veselova, V. Rozhansky et al, Predictive modeling ofthe JET D–T plasma boundary, *Contrib. to Plasma Phys.* (2023) e202300118

[5] Makarov S O, D.P. Coster, E.G. Kaveeva et al, Implementation of SOLPS-ITER code with new Grad–Zhdanov module for D–T mixture, *Nucl. Fusion* **63** (2023) 026014

[6] I.Yu.Senichenkov, R.Ding, P.A.Molchanov et al, SOLPS-ITER modeling of CFETR advanced divertor with Ar and Ne seeding, *Nucl. Fusion* **62** (2022) 096010