THE RADIATIVE DIVERTOR AND IN/OUT ASYMMETRY IN HL-2M BY IMPURITY SEEDING WITH FULL DRIFTS

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1. ABSTRACT

The power exhaust on the plasma-facing comments (PFCs), especially for the divertor, is much challenging for the HL-2M[1]. Radiative divertor has been proposed for standard divertor (SD) by neon (Ne) or argon (Ar) seeding. In this work, the effects of toroidal magnetic field direction, divertor geometry and impurity species on the divertor in/out asymmetry has been investigated, with emphasis on the impacts of full drifts[2]. The simulation results show that: (1) More Ne particles accumulate in the divertor region with full drifts than that of without drifts. Moreover, the divertor in/out asymmetry is significantly reduced with unfavorable magnetic field (ion $B \times \nabla B$ drift is directed away from the primary X-point). (2) The shrinkage of dome can mitigate the capabilities of pump, significantly affecting the Ne ions distribution and the in/out asymmetry. (3) The upstream D_2 fueling can remarkably promote the impurity screening and affect the Ne distribution, and then influence the in/out asymmetry. (4) The impurity screening with Ar seeding is better than that of Ne seeding. However, the core radiation with Ar seeding is higher than that of Ne due to the high Ar radiative efficiency.

2. KEY RESULTS

(1) By comparing the Ne seeding cases for forward, no and reversed drifts in SD, it is shown that drifts can remarkably enhance the main plasma conditions. More Ne particles are compressed to the divertor for drifts case than that of no drifts case due to the increase of D^+ flux in the core by drifts. Moreover, the reversed drifts cases have a better in/out asymmetry, while the in/out asymmetry for the forward drifts cases are much intense due to the combined effects between divertor geometry and the E×B drift.

(2) The effects of dome modification on the in/out asymmetry and impurity screening are investigated. It is found that the shrinkage of dome can mitigate the pump capabilities, significantly affecting the Ne ions distribution and the in/out asymmetry. Moreover, the outer dome shrinkage is more efficient on the divertor Ne compression due to the associated effects between drifts and divertor geometry.

(3) By the D_2 fueling at upstream scan for reversed drifts with fixed Ne seeding (5×10^{19} Ne atoms/s), it demonstrates that the upstream D_2 fueling can remarkably benefit the impurity screening and affect the Ne distribution, and then influence the in/out asymmetry.

(4) The core radiation for reversed drifts with Ne or Ar seeding is higher than that of forward drifts due to the strong diamagnetic inflow drives more impurities to the core region for the reversed drifts. Additionally, the impurity screening with Ar seeding is better than that of Ne seeding. However, the core radiation with Ar seeding is higher than that of Ne due to the high radiative efficiency of Ar.

3. IMPACT AND NOVELTY

This study provides new insights into impurity transport, screening, and divertor in/out asymmetry in HL-2M using SOLPS-ITER simulations. It reveals that full drifts enhance impurity compression, while an unfavorable magnetic field increases core contamination. Additionally, dome shrinkage weakens pumping efficiency, affecting

Ne distribution, and upstream D_2 fueling improves impurity screening. Finally, Ar seeding offers better impurity screening than Ne but leads to higher core radiation. These findings contribute to radiative divertor optimization, providing key guidance for future tokamak operation. However, some issues remain to be investigated: (1) the assessment of sputtering tungsten impurities in SD and snowflake divertor; (2) snowflake radiative divertor with active full drifts and secondary XP.

4. METHODOLOGY

This study employs SOLPS-ITER[3] to investigate impurity transport and power dissipation in the HL-3 lower single null (LSN) configuration, considering both forward and reversed toroidal magnetic field directions. The multi-fluid transport code B2.5 is coupled with EIRENE to model plasma and neutral interactions. Tungsten (W) PFCs are assumed, but W impurities are excluded due to their negligible edge impact and high computational cost. D_2 fueling at the outer midplane (OMP) enhances impurity screening via puff-and-pump effects, while Ne or Ar seeding at the outer strike point (OSP) optimizes divertor power dissipation. A quasi-orthogonal mesh for B2.5 and a triangular mesh for EIRENE ensure accurate transport modeling.

5. FIGURES

To clarify the associated effects of E×B, Pfirsch-Schlüter (PS) and diamagnetic flux on the Ne impurities transport, the sketch of E×B, PS and diamagnetic flux of D^+ in the physical domain in SD for the forward and reversed drifts case are shown in Fig. 1. The core radiation for forward and reversed drifts with Ne and Ar seeding as the increase of divertor radiation are shown in Fig. 2. It can be seen that the core radiation for forward drifts with Ne seeding is lowest for fixed divertor radiation.

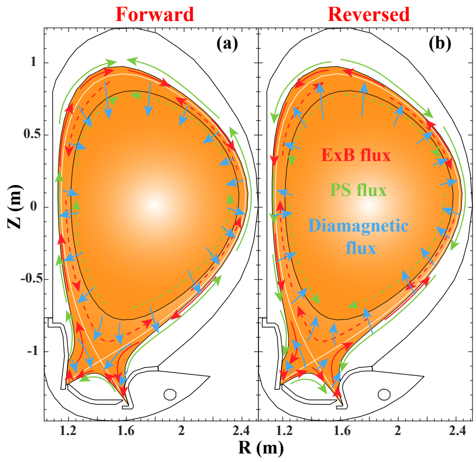

Fig. 1 The direction of E×B, PS and diamagnetic flux of D^+ in the forward (a) and reversed (b) drift cases.

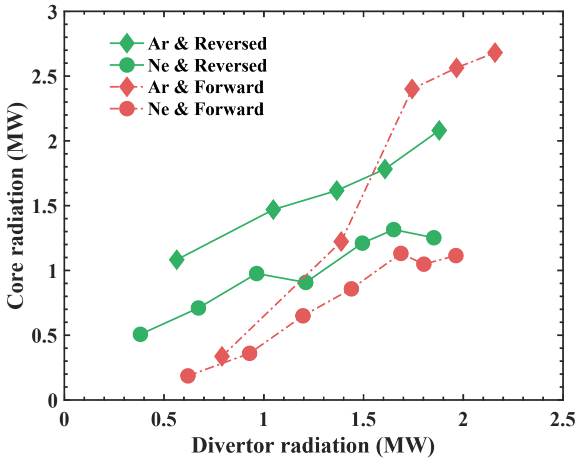

Fig.2 The core radiation for forward (red) and reversed (green) drifts with Ne (circle marker) and Ar (diamond marker) seeding, as functions of divertor radiation.

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