The effect of target shaping on impurity retention and pedestal performance in the slot divertor at DIII-D

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Impurity seeding studies in the Small Angle Slot (SAS) divertor in DIII-D show a strong relationship between both detachment onset and pedestal performance with target shaping and impurity species. Future reactors will need to operate with impurity seeding and detached divertor conditions to reduce erosion and power loads on divertor components. Understanding how to simultaneously fulfill the competing needs of a detached divertor which requires high density and the plasma core which operates at low collisionality is critical for the design and operation of future reactors. In this work we show that the combination of divertor closure and impurity seeding can enable improved core-edge compatibility by controlling neutrals and impurity distribution through variations in strike point location in a closed slot divertor.

Divertor detachment of H-mode discharges without core performance degradation is induced by puffing N_2 in the slot, leading to the first simultaneous observation of detachment on the entire boundary diagnostics viewing the SAS. For matched discharges, when the strike point is at the outer corner of the slot, 20% higher core impurity content is measured than when the strike point is at inner surface. Additionally, the detachment onset measured as the J_{sat} roll over and T_e drop requires roughly double the amount of nitrogen when the OSP is at the outer corner for the ion-grad B drift toward the X-point. SOLPS-ITER simulations with D+C+N, drifts and n-n collisions activated are performed in DIII-D for the first time highlighting an important dependence of the recycling source on target shaping. The realistic magnetic geometry from EFIT equilibrium fitting code is used for both the strike point locations used in the experiments. The inclusion of drifts in the simulations shows the importance of convection in moving particles towards the inner target. It is shown that the different distribution of the recycling source due to the different strike point locations has significant consequences on the plasma flow. The impurity transport in the divertor which strongly depends on the main ion flow and drifts is also investigated. A flow reversal is found for both main ions and impurities. The different 2D flow distributions corresponding to the different strike point locations can explain qualitatively the experimental observation of reduced N_2 content in the core and the less N_2 amount needed for the detachment with OSP on the slanted inner surface. Experiments where N_2 was replaced by Ne injection have been also carried out showing the different pedestal response of SAS to the two radiative species. While not much nitrogen penetrates in the core, a significant amount of Ne is found in the pedestal consistent with the different ionization potential for the two impurities. Neon leads to an increased pedestal pressure gradients and improved pedestal ballooning stability through increased diamagnetic stabilization.

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