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Studies of power load with localised neon injection in HL-2M

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The controllability of the power exhaust in the divertor could be one of the critical problems to be solved in order to ensure the success for a steady state tokamak[1]. Impurity seeding is an important tool to mitigate the peak power loads and temperatures at the divertor targets in tokamak devices[2]. Experiments with impurity(neon, nitrogen, argon, etc) seeding have been carried out on machines worldwide, especially for large-size devices such as JET and JT-60U, impurity gas seeding has been ascertained to be a good solution for controlling the heat loads on divertor targets. However, in most cases, the impurity will be injected through one or a set of toroidally distributted localized gas valves situated below the divertor cassettes, in which case the spatial localization of the impurity source may result in toroidal asymmetries in the raidated power and the heat flux to the divertor, even more worse if the extrinsic gas is only partially recyling[3,4]. To improve the physics understanding and provide predictive capabilities for the impact of impurity seeding on the plasma and mitigate the heat loads, different impurity seeding methods have to be investigated and compared to each other.

In this paper, we report the first 3D EMC3-EIRENE simulations of neon seeded H-mode plasmas in HL-2M. EMC3-EIRENE is a 3D edge plasma fluid and neutral particle transport code. As a primary and fairly important step, the implementation of EMC3-EIRENE to HL-2M and the validation against the 2D simulations with SOLPS has been carried out, showing a quantitively good agreement. The neon impurity seeded at different poloidal positions has been investigated to understand the properties of impurity concentration and heat load distributions for a single toroidally localised injection and multi-toroidally distributed injections. The investigated gas puffing cases include the divertor, midplane and top gas puffing. The majority of the studied neon injections gives rise to a toroidally asymmetric profile of heat load deposition on the inner or outer divertor targets. It has been found that the level of toroidal asymmetry in divertor conditions resulting from single toroidally localized divetor impurity seeding show a much more stronger toroidal peaking in heat loads and divertor electron temperatures and pressures compared to the other poloidal injections. However, the heat loads cannot be reduced below the acceptable level along the whole torus for a single toroidally localised injection. The influences of gas puff rate and particle transport parameters on the SOL density are investigated. The parameter scans indicated that the high neon injection flux results in the highest neon particles density and energy loss in the edge plasma, which leads to an effective mitigation of heat load(as shown in Figure1). In addition, the neon injection on the outer midplane was found to give rise to an undesirable level of Zeff at the pedestal region, which in contrast the neon impurity was screened to an acceptable level for the divertor neon injection case.

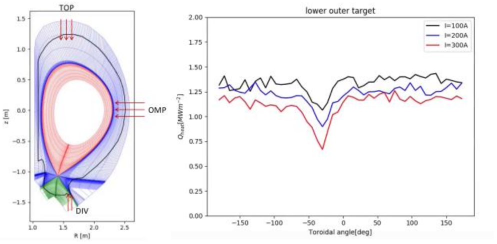

Figure 1. Left: Poloidal cross-section of HL-2M shows the gas route puffed from different gas valves. Right: The toroidal distributions of heat flux deposition on the outer targets with various gas puff rates.

In order to achieve the heat load mitigation along the entire torus, modelling of single and simultaneous multi-toroidal neon injections near the outer strike points has been simulated, which indicates that the simultaneous multi-toroidal neon injections show a better heat flux mitigation on both outer divertor targets. In addition, it is found that the increased number of neon toroidal injection locations can cause a relatively uniform reduction of heat loads along the entire torus(as shown by Figure 2).

From our studies, it can be inferred that using divertor gas valves closer to the strike point is the optimized way in terms of minimizing heat power loading on the targets. Further studies will be focus on the scenarios of combined gas puffing from multi-toroidal positions and give more qunatitative predictions of heat load mitigation and impurity contamination. This work is supported by the national key R&D program of China under grant No. 2022YFE03030002 and the national natural science foundation of China under grant No. 12275072.

References

[1] R. Behrisch and V. Prozesky, Nucl. Fusion **30** 2166(1990).
[2] A Kallenbach et al., Plasma Phys. Control. Fusion **55** 124041 (2013).
[3] J. Rapp et al., Nucl. Fusion **44** 312 (2004).
[4] J.D. Lore et al., Phys. Plasmas **22** 056106 (2015).

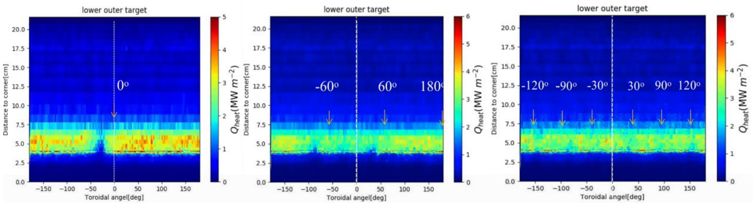

Figure 2. Heat flux distribution on the outer target for the neon injection at the divertor under (a)single (b)three (c)six toroidal positions. The toroidal positions for gas valve are denoted by the arrow.