Impact of leakage under divertor baffle on detachment onset in WEST with SOLEDGE3X-EIRENE modeling

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Abstract

The effects of variation in baffle closure caused by the sealing of leaks below the outer baffle in WEST tokamak are studied through the numerical simulations performed with SOLEDGE3X-EIRENE transport code. We investigated the density regimes analyzing how parameters like density, temperature, particle flux, and neutral pressure evolve as functions of gas puff rate and upstream separatrix electron density $n_{e,sep}$ comparing among the cases with and without leak. The results show that the case without leak has better performance than the cases with leak in trapping the neutral particles and has higher neutral pressure near the baffle by more than 35%, which can lead to greater power dissipation in the divertor, thus lower the detachment threshold in upstream $n_{e,sep}$ by more than 10%. At the same time, the operational gas puffing range becomes broader by a factor from 1 to 5 in the case without leak with respect to the three cases with leak. However, a significant negative proportional relationship observed between the detachment threshold in upstream $n_{e,sep}$ and that in the puff rate as a function of the variable baffle leakage. With better baffle closure, the relative decrease in upstream separatrix density threshold is much smaller than the relative increase in puff rate threshold.

Keywords: detachment, SOL, divertor baffle closure, leakage effect

1. Introduction

The WEST (W-tungsten Environment in Steady-state Tokamak) is the transformation of the Tore Supra tokamak from a carbon limiter to a tungsten divertor configuration [1]. In recent experiment campaign C5, the divertor pumping capability has been improved by the sealing of the space between the divertor baffle and the vacuum vessel. This modification leads to an interesting question about how the variation in baffle closure caused by the sealing of leaks will influence the plasma in WEST. To investigate this question, we made simulations of four cases with leakage scan by the help of SOLEDGE3X-EIRENE code [2]. Four configurations are shown in figure 1, they are just different at the bottom part of baffle, but have the same top part in order to exclude the possible influence of recycling on the baffle [3]. All the cases have the same simulation setup listed in table 1. In section 2, we investigated the difference of those cases based on the gas puff rate scan. In section 3, comparison based on the ramped electron density at the outer midplane separatrix, $n_{e,sep}$. In section 4, discussion and conclusion.

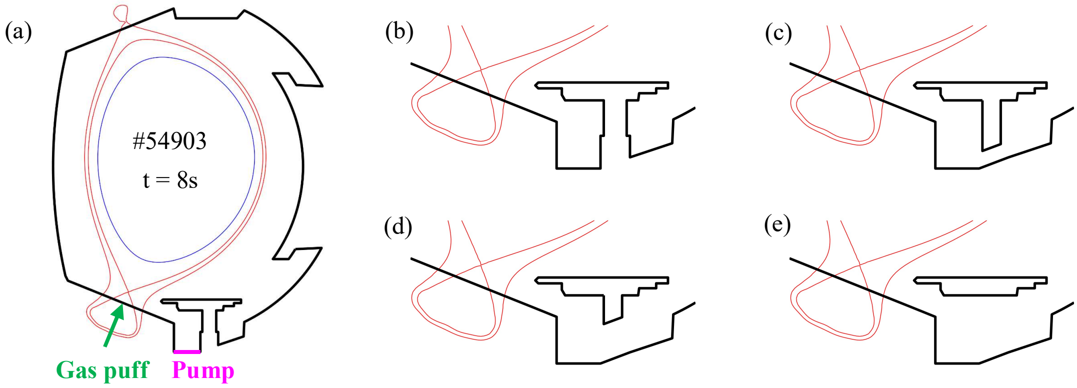

Figure 1. (a) WEST LSN magnetic configuration with wall geometry in the poloidal cross-section. The black solid line represents the chamber wall, the red solid lines represent the separatrix, the blue solid line represents the core boundary, the green arrow represents the gas puff position, the magenta line represents the pump position. (b - e) Baffle of the case with no leak, the case with small leak, the case with medium leak, and the case with big leak.

Plasma composition	Recycling coefficient	SOL input power	Gas puff rate	Drifts	Transport coefficients
Pure deuterium	Rwall = 1 Rpump = 0.95	0.449MW	1e20 - 1.2e21 mol/s	No	$\boldsymbol{D}$ = 0.3 m^2/s $\boldsymbol{\nu}$ = 0.3 m^2/s χ_e,χ_i=1 m^2/s

Table 1. The setup parameters for simulation

2. Comparison based on gas puff rate scan

Firstly, we tried to evaluate peak electron particle flux Γ_e on the outer target and upstream $n_{e,sep}$ based on the gas puff rate scan. It can be observed that three cases with leak have narrower operation gas puffing range by more than 50%, have earlier access to detachment, and have lower peak Γ_e corresponding to the rollover, comparing with no leak case. From the comparison of upstream separatrix density profiles, a significant negative proportional relationship exists between the detachment threshold in $n_{e,sep}$ and that in the puff rate, the relative change in upstream $n_{e,sep}$ threshold is much smaller than the relative change in puff rate threshold. Leakage under baffle results in the increase of neutral density by a factor of 2.5 - 6 in low filed side and ~ 1.5 in high field side of the main chamber comparing between the case without leak and the case with small leak. The upstream separatrix density is higher in the case with lower baffle closure because of more neutral ionization sources outside separatrix.

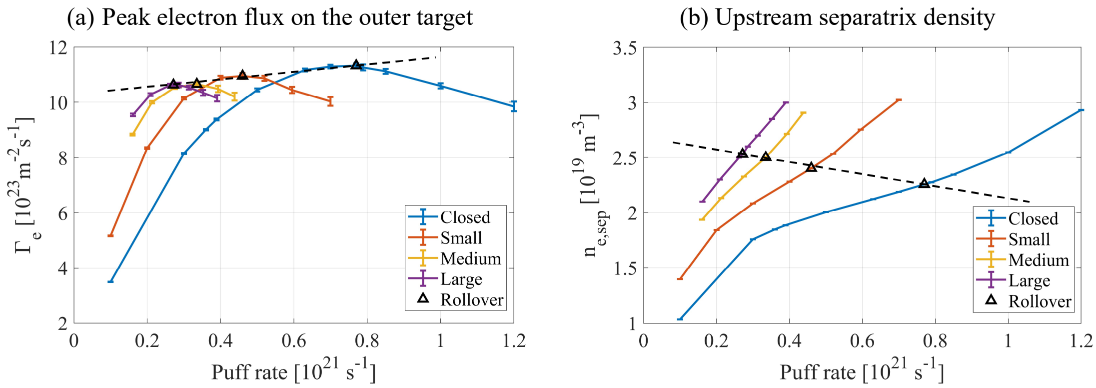

Figure 2. (a) Peak electron flux profiles on the outer target, the triangle on each curve marks the corresponding rollover point, the dashed line through each triangle represents a positive proportional relationship between the rollover Γ_e and corresponding puff rate. (b) Upstream separatrix density profiles on the outer midplane, the dashed line through each triangle represents a significant negative proportional relationship exists between the detachment threshold in $n_{e,sep}$ and that in the puff rate.

3. Comparison based on upstream separatrix density scan

A lower neutral compression ratio has been observed in the case with better baffle closure, which means better performance in trapping the neutral particles and has higher neutral pressure near the baffle by more than 35%. This leads to greater power dissipation in the divertor, thus lower the detachment threshold in upstream separatrix density by more than 10%. The earlier detachment in better closure case can also be observed in the profiles of X-point radiator height.

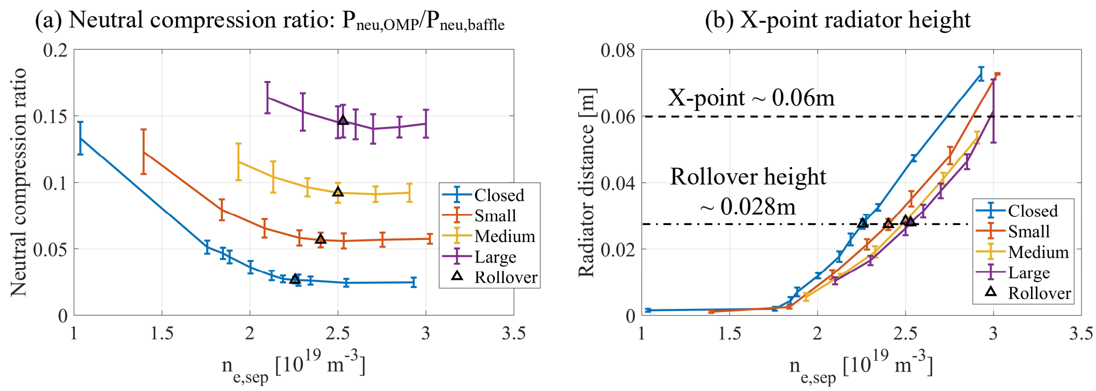

Figure 3. (a) The profiles of the neutral compression ratio (ratio of neutral pressure on the near-wall outer midplane position and the pressure below baffle position) as a function of upstream separatrix density. (b) The profiles of the vertical distance between the position of the peak of radiated power and target. The X-point height is about

6cm, and the height of the position of the peak of radiated power is always around 2.8cm when the rollover happens for all the cases we have considered.

When rollover happens in each case, the peak radiation height is always around 2.8cm, the peak electron temperature on the outer divertor is around 2eV. This temperature result is consistent with what has been observed in DIII-D experiment, Te dropped to 2eV when the rollover in peak J_{sat} happened [4]. This phenomenon is probably due to the combination of two factors: hydrogen ionization happens at Te ~ 2-5eV and plasma recombination happens at Te ~ 1eV [5].

4. Discussion and conclusion

Simulation results show that there exists rollover characteristic target temperature ~ 2eV and that of X-radiator height ~ 2.8cm, on which the variable baffle closure has no obvious influence. The case without leak has better performance than the case with leak in trapping the neutral particles and has higher neutral pressure near the target, which can lead to greater power dissipation in the divertor, thus decreasing the detachment threshold in upstream separatrix density. However, to obtain the same upstream separatrix density in the case without leak, one needs to ramp the gas puff rate to a higher value with respect to the leak case due to fewer ionization sources outside the separatrix. With better baffle closure, the peak Γ_e corresponding to the rollover is higher, and the relative decrease in upstream separatrix density threshold is much smaller than the relative increase in puff rate threshold. Simulation results will be confronted with experimental data from the configurations with and without leak under the baffle in order to get further insight on the particle circulation in WEST.

5. Acknowledgements

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

6. References

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