SOLPS-ITER simulations of the initiation of an X-point radiator in the ASDEX Upgrade tokamak

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The X-point radiator (XPR) is an attractive scenario that may contribute to solving the power exhaust problem in future fusion devices [1]. Recently, a series of experiments was carried out on AUG to study the operational window of the XPR. A reduced model [2] was derived to explain the physical mechanisms for initiating a stable XPR. However, 2D numerical simulations are required to interpret the experimental observations not caught by the reduced model, including the spatial distribution of sources, cross-field transport and the high-field-side/low-field-side asymmetry of an XPR. In this work, the SOLPS-ITER transport code [3] was applied. The simulation was able to reproduce the density and temperature profiles measured by the divertor Thomson scattering and the profiles measured at the upstream position simultaneously.

Neutrals penetrating from the adjoining cold divertor region and the large connection length near the X-point play an important role in initiating an XPR. In the simulations, it was not possible to achieve an XPR when an absorbing baffle was added artificially to hinder neutrals penetrating the confined region near the X-point, highlighting the role of neutrals. With the same impurity seeding rate, the simulation with a higher toroidal field showed an XPR deeper inside the confined region, indicating that a larger connection length can enhance volumetric processes and promote the evolution of XPR. Below a certain plasma temperature in the X-point region, the source of particles that recycled in the detached divertor decreased, and the strong ionization inside the XPR was mainly supplied by neutrals from local volumetric recombination.

The high-field-side/low-field-side asymmetry of plasma density and radiation inside the XPR was studied in experiments and simulations in favourable and unfavourable field directions. Compared to the cases without drifts, simulations with drifts in both field directions presented a lower density inside the XPR on the high-field side, showing a better agreement with the divertor Thomson scattering measurements. This could be explained by the plasma potential hill (well) near the X-point with the favourable (unfavourable) field direction, and the clockwise $E_\theta \times B$ particle advection above the X-point [4, 5]. It was also found in the simulations that the XPR influenced the radial electric field profile at the upstream position.

References

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