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Kinetic modeling of tungsten impurity transport using the IMPGYRO code

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With the move in current and future fusion devices to all-metal walls, and particularly with tungsten (W) plasma-facing components, understanding heavy ion impurity transport processes in the Scrape-Off Layer (SOL)/divertor region is becoming one of the most critical issues for tokamak operation. To improve this understanding, we are continuing to develop the kinetic SOL/divertor impurity transport code IMPGYRO (IG), which tracks the trajectory of impurity ions in the plasma, resolving their full gyro-orbits.

For the W transport in the SOL/divertor region, the friction force, the thermal force, the E×B drift and the anomalous radial transport are traditionally regarded as the dominant factors. In addition to these, it has recently been pointed out that neoclassical transport processes can have non-negligible effects on transport in the SOL/divertor region. In this paper, we mainly focus on neoclassical transport processes associated with the parallel transport of W impurities in single null divertor configurations.

We focus the IG simulations using a plasma background obtained with the SOLPS5.0 plasma boundary code suite on the magnetic equilibrium of the JT-60U pulse #49540. When the background plasma is in a high recycling state, the W particles have been pushed upstream by the strong thermal force and transported to the top region of the SOL due to the existence of a steep parallel temperature gradient in front of the divertor plate. The W particles then stagnate near the top of the SOL where the parallel thermal force and the friction force are in balance. The W impurities then penetrate into the main plasma due to the grad-B drift and curvature drifts, which are automatically taken into account in the IG modelling, causing a net inward perpendicular flux.

In order to better understand the W penetration process, we compare the IG model to a simpler guiding centre model with an anomalous transport. We find that in general the IG radial velocities tend to be larger than those from the guiding centre model. As a consequence, localized impurities have a larger radial flux in the IG calculation. The results suggest that not only the anomalous diffusion but also the drifts, specifically the grad-B drift and the curvature drift, should be taken into account in order to correctly predict the W core accumulation.

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