Impact of divertor target material and gas puff location on ITER divertor performance

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The current ITER divertor design is based on an extensive set of SOLPS-4.3 simulations for burning plasma conditions with power into the scrape-off layer (SOL), P_{SOL} = 100 MW and low Z impurity neon (Ne) seeding [1]. Along with a fixed choice of cross-field transport coefficients for particles and heat, two key assumptions were made in constituting this database: that all fuel and impurity gas puffing is performed from an upper low field side main chamber port location, and that the tungsten (W) divertor targets are coated with beryllium (Be) originating from main wall erosion and subsequent migration. Gas injection will, however, be possible, and may now even be operationally more likely, from the bottom of the vacuum vessel, below the divertor cassettes. Likewise, the precise extent to which Be will coat the divertor target is still uncertain, with recent migration calculations indicating that Be coatings may not form in the strike point regions which are the most important from the point of view of power handling. The impacts of these two assumptions (gas puff location and divertor target surface material) are assessed here by means of SOLPS-ITER simulations, considering plasmas typical of the Pre-Fusion Power Operation-1 (PFPO-1: P_{SOL} = 20 MW, hydrogen (H) fuel) and Fusion Power Operation (FPO: P_{SOL} = 100 MW, D fuel, He fusion ash, and Ne seeding) phases.

We find that the divertor surface material mainly influences the fuel recycling split between fast particle reflection as atoms and thermal reflection as molecules, affecting the divertor performance by changing the balance between atom-plasma and molecule-plasma interactions. In the case of the high recycling/partially detached regime of PFPO-1 plasmas, however, the atomic and molecular contributions to the momentum and power losses compensate each other, so the overall effect is negligible. However, for FPO plasmas, when a W divertor surface and SOL puffing are used, higher Ne concentration and greater in-out asymmetry in the Ne radiation, for the same fuel and Ne throughput, are found, when compared to Be divertor surfaces. This appears to be due to the very significant difference in energy reflection of the Ne particles from the two different material surfaces.

The ITER SOL plasma is opaque to neutral particles in both the PFPO-1 and FPO phase simulations. The injected fuel represents only 1-10% of the recycled flux from the target across the divertor neutral pressure range covered by the simulations. Fuel particles recycled at the target and gas puffed at the divertor are mostly confined within the private flux region and the upstream density saturates with increasing throughput, even under low power, PFPO-1 conditions. However, neutrals puffed from the top of the main chamber, are ionized in the main chamber SOL, contributing directly as an upstream ionization source, accelerating the transition of the divertor to a high recycling regime. The impact of fluid drifts on the low power, H-only simulations with the different divertor target material and gas puffing locations will also be examined.

[1] R.A. Pitts et al., Nucl. Mater. & Energy **20** (2019) 100696.