Particle fueling and exhaust in the Wendelstein 7-X island divertor

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A single-reservoir particle balance for the main species hydrogen has been established for Wendelstein 7-X (W7-X). This has enabled the quantitative characterization of the particle sources and sinks in the standard Island Divertor configuration for the first time. Findings from attached to first results for detached divertor scenarios are presented. Fueling efficiencies, flux balances and source locations were measured and used to infer the total particle confinement time. Perturbative gas injection experiments served to measure the effective particle confinement time τ_P^*. Combining both confinement times provides access to the overall recycling coefficient R. Hydrogen and helium particle inventories have been addressed and the knowledge of particle sources and sinks provides insight into the capability of the magnetic island size and shape to control exhaust features.

The global particle balance revealed that no significant difference in the fueling efficiencies from up- and downstream gas fueling was found for H, and that overall the fueling efficiency of He was about 60 % higher. The recycling fluxes of the divertor and wall were found to govern the particle source. It was shown that in attached scenarios, 57 % of recycled particles came from the divertor, while the remainder of the overall recycling flux source was distributed between the baffle (9 %), heat shield (22 %) and steel panels (12 %). τ_P values in the range of 100 - 120 ms, depending on the exact density, were extracted for these discharges.

Together with τ_P, the global recycling coefficient R was calculated for every τ_P^* measurement and a typical value close to unity was obtained. This indicates that the wall reservoir was in the transition between small absorption or small desorption, depending on the density level of the previous discharge and the duration of the current discharge. An increase of the island size and shape through a control coil current, resulted in no change of τ_P but doubled τ_P^*, indicating the feasibility of the control coils as an actuator for stable divertor operation. The increase of the control coil current shifted 22 % of the particle flux, and therefore the recycling neutral source, from the divertor to the graphite tiles of the first wall shield. This led to more neutrals in the main chamber, which was detected in an increase of the neutral pressure by 23 %, and is consistent with the observed increase in τ_P^*. In addition, an increase of the radiated power by 51 % was seen in the scrape-off-layer (SOL), which was connected to an increase in the abundance of carbon impurities. Camera data indicated that the carbon flux on the heat shield increased, due to the particle load increase observed that could cause an increase in first wall erosion. First assessment of detached divertor conditions shows that the fueled particle flux was fully balanced by the pumped flux with a constant wall source. The particle confinement time τ_P doubled to levels of 250 ms for these discharges. This is a result of a decrease of the overall recycling flux at an increased density level in equilibrium between sources and sinks.

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