Enhancement of helium exhaust during RMP-ELM suppression at DIII-D and analysis with 3-D edge fluid and kinetic neutral code EMC3-EIRENE*

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Resonant magnetic perturbation (RMP) fields used to suppress Edge Localized Modes (ELMs) in high confinement (H-mode) tokamak plasmas were found to lead to a strong enhancement of helium exhaust in recent experiments at DIII-D. The effective He particle confinement time $\tau^*_{p,\,He}$ in ELM-suppressed H-modes was reduced by 40% compared to unsuppressed discharges, and $\tau^*_{p,\,He}/\tau_E$, where τ_E is energy confinement time, was reduced by 10-20%. These first-time findings are important for ITER, where application of RMP fields is planned for ELM control, as they suggest RMP fields can replace the impurity exhaust produced by the ELM events.

Increased helium exhaust was measured for ITER-shaped plasmas at DIII-D using argon-frosted divertor cryo-panels for active pumping of He, which was injected in short test pulses into a deuterium plasma. A multiple-reservoir particle balance model was used for analysis of the experimental data. In both the plasma edge and core reservoirs, midplane He density measurements from charge-exchange spectroscopy show reduced n_{He} and a faster decay time during ELM suppression, suggesting faster outward transport and/or reduced He back-fueling after recycling. Increased He-I and He-II emission in the Scrape-off Layer (SOL) and increased neutral He pressure in the pumping plenum show that more He is retained in the SOL and neutral reservoirs, which is important for effective removal of He from the entire plasma. EMC3-EIRENE fluid plasma edge and kinetic neutral transport modeling of comparable scenarios, in addition to the experimental measurements, suggests two mechanisms behind the beneficial enhancement of helium exhaust. First, reduced parallel temperature gradients due to magnetic field stochastization in the vicinity of the separatrix can increase the friction force acting on impurities relative to the thermal force, which enhances outward transport in the region of the perturbed magnetic field. Second, the evolution of helical lobes, which connect the separatrix region to the divertor via a helical magnetic footprint, yields increased He neutral pressure due to increased divertor plasma plugging. Both effects are being analyzed with dedicated EMC3-EIRENE modeling including plasma response from M3D-C1 extended MHD code, which defines the level of magnetic field stochastization at the separatrix.

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