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Enhancement of helium exhaust during suppression of edge localized modes by resonant magnetic perturbation fields at DIII-D

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It is shown for the first time that global exhaust of helium, measured by effective helium particle confinement time (⊠p,*He), is improved during edge localized mode (ELM) suppression by resonant magnetic field perturbations (RMP) in high confinement (H-mode) ITER-shaped tokamak plasmas at DIII-D. An up to 40% reduction of ⊠p,*He during RMP-ELM suppression compared to ELMy H-mode discharges without RMP fields was measured using He test pulses in the upper outboard midplane. The ratio ⊠p,*He/⊠E is reduced from 13 to 11 during RMP ELM suppression, showing that the improvement in He removal from the system exceeds the impact of RMP fields on energy confinement, bringing this ratio closer to the canonical threshold for a fusion reactor of ⊠p,*He/⊠E<10\.
To understand the cause of this important observation, we assess the changes to He confinement and exhaust in a three-reservoir model consisting of the core, plasma edge/SOL, and neutral reservoirs. Global He exhaust from the system depends on the exhaust from the confined plasma domain into the SOL and the neutral reservoir, where neutralized He is eventually removed by the pump. However, the removal rate (pumping efficiency) for He is low, and it recycles many times before being pumped. Therefore, retaining He in the plasma peripheral regions (SOL and neutral domain) without back-fueling of the plasma is vital for the He exhaust cycle.
Measurements of He and D2 neutral pressures in the pump plenum from Penning gauges show the partial pressure of He increases substantially more than that of D2 during RMP-ELM suppression, in comparison with the ELMing H-mode. This selective increase in He concentration suggests a preferential enhancement of He exhaust into the neutral domain, rather than a simple link to main species 'pumpout', and provides substantial evidence of strong He retention in the plasma periphery during RMP ELM suppression, which is a necessary condition to improve removal of He from the system. The He density in the edge confined region measured with charge exchange recombination spectroscopy also shows an enhanced rate of decay during RMP ELM suppression. These first-time findings are important for ITER, where application of RMP fields is planned for ELM control, as they suggest application of RMP ELM suppression could replace the impurity exhaust produced by the ELM events.

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Author: Dr HINSON, Edward (University of Wisconsin-Madison)

Co-authors: Dr BRIESEMEISTER, Alexis (ORNL); Mr GRIERSON, B.A. (Princeton Plasma Physics Laboratory); Dr COLLINS, Cami (General Atomics); Dr PAZ-SOLDAN, Carlos (General Atomics); Dr THOMAS, Dan (General Atomics); Dr UNTERBERG, Ezekial (Oak Ridge National Laboratory); Dr FRERICHS, Heinke (University of Wisconsin-Madison); Dr BYKOV, Igor (University of California San Diego); Dr WADE, Mickey R. (General Atomics); Prof. SCHMITZ, Oliver (University of Wisconsin - Madison, Department of Engineering Physics); Dr MOYER, Richard (University of California San Diego); Dr EVANS, Todd E. (General Atomics); Dr ABRAMS, Tyler (General Atomics)

Presenter: Dr HINSON, Edward (University of Wisconsin-Madison)

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