Effect of the Externally Seeded Impurities on Pedestal Turbulence and ELMs

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To control the ELMs and to protect the PFCs in burning plasma devices, impurity seeding experiments have been performed on JET, ASDEX-U, DIII-D. Recently, ELM control experiments with LBO-seeded impurity have been successfully achieved on HL-2A [1]. It has been found that the ELM mitigation and ELM suppression could be realized by seeding different quantity impurities. The thresholds in impurity density of iron (Fe) and aluminum (Al) for mitigating and suppressing ELMs have been statistically analyzed. During ELM mitigation by impurities, it has been found that the turbulence intensity is increased by reducing the pedestal $v_{E\times B}$ shear rate, which is similar to the results of the ELM mitigation experiments with LHCD [2,3]. It has been shown that the modification of the pedestal $v_{E\times B}$ shear rate by LHCD is due to its ion diamagnetic term $\nabla(\nabla P_i/n_i q_i)$. However, it has been demonstrated that the reduction of pedestal $v_{E\times B}$ shear rate by impurity seeding is attributed to its toroidal velocity term $\nabla(v_\phi B_\theta)$ in which the ion toroidal velocity v_ϕ is increased. Unexpectedly, the ions are accelerated in the toroidal direction, although the flow damping should be enhanced due to the increasing of the electron-ion collision rate by impurity seeding. During ELM suppression, the pedestal turbulence is significantly reduced. This reduction of the turbulence could result from the decreasing of the linear growth rate of the ITG mode as predicted by the theoretical simulation. Results from HL-2A show a potential approach to control the ELMs by regulation of the pedestal turbulence when appropriately controlling the spatial distribution and quantity of the impurity at the pedestal.

[1] Y.P. Zhang et al., Nucl. Fusion **58,** 046018 (2018)
[2] G.L. Xiao et al., Nucl. Fusion **59**, 126033 (2019)
[3] G.L. Xiao et al, Phys. Plasmas **26**, 072303 (2019)