Impurity transport driven by parallel velocity shear turbulence in hydrogen isotope plasmas

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Turbulent impurity transport driven by parallel velocity shear (PVS) turbulence in hydrogen isotope plasmas is studied using the gyrokinetic theory in a slab configuration with weak magnetic shear. The quasi-linear impurity flux written in terms of diffusion and convection is analytically derived. It is found that PVS turbulence leads to an inward impurity convection. For high temperature helium ash from deuterium (D) and tritium (T) reaction, as shown in Figure 1, the turbulent impurity flux could be outward because the impurity diffusion dominates over the inward convection. Therefore, PVS turbulence might be beneficial for removing high temperature helium ash in future burning plasmas. Moreover, both the outward flux and diffusivity of helium ash are enhanced by increasing PVS, but reduced by decreasing the temperature of helium ash. For fully ionized light impurities with finite concentration and the trace heavy metal impurities, the stronger sheared parallel velocity as well as the steeper parallel velocity profile, the more serious accumulation of impurity, as shown in Fig. 2. Thus, PVS turbulence might be a partial explanation for experimental observation of impurity accumulation in the neutral beam heated plasmas. While, the increase of the electron density gradient may be favorable for stabilizing the PVS mode and easing the accumulation of impurities from plasma-wall interaction or external injection. Furthermore, isotopic effects (increasing the effective hydrogen isotope mass number) are favorable for both removing helium ash and easing the accumulation of heavy metal impurities induced by PVS turbulence. More implications of these theoretical results to the future burning plasmas are discussed.
The published paper can be found in [1].

In the figures:
$f_c = n_{0z}/n_{0e}$ is the impurity concentration, $\tau_\alpha = T_e/T_\alpha$ is the temperature ratio between electron and impurity, R is the major radius. $L_{ne} = -n_{0e}/\nabla n_{0e}$ and $L_{U_\parallel} = -U_\parallel/U_\parallel^{'}$ represents the electron density gradient scale length and the PVS scale length with $U_\parallel^{'} = \partial U_\parallel/\partial r$ being the PVS.

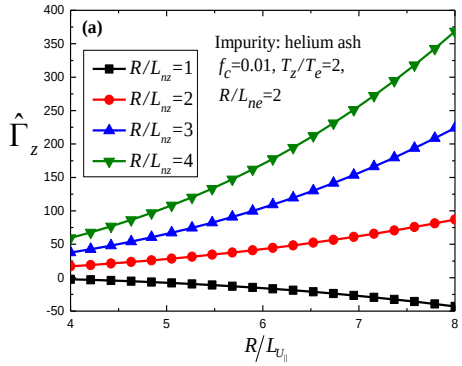

Fig. 1. The turbulent flux of helium ash $\hat{\Gamma}_z$ versus the normalized PVS.

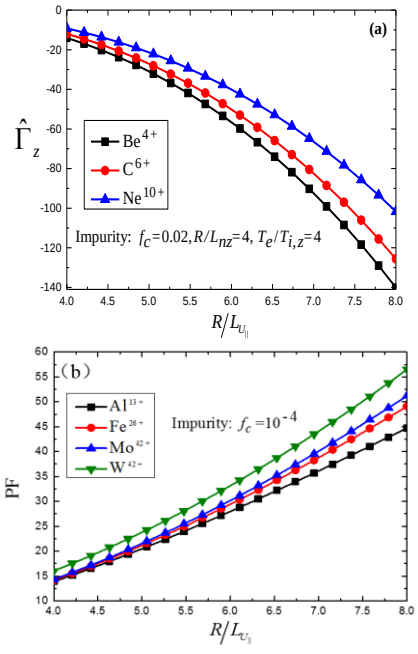

Fig. 2. The turbulent flux of helium ash $\hat{\Gamma}_z$ and peaking factor (PF) of helium ash versus the normalized PVS.

Ref.

[1] Weixin Guo, Lu Wang*, Ge Zhuang, "*Impurity transport driven by parallel velocity shear turbulence in hydrogen isotope plasmas*", Nucl. Fusion 59 076012 (2019).