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Investigation of fast particle redistribution induced by sawtooth instability in NSTX-U

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The effects of sawtooth on fast ion transport have been studied in reproducible, 2 seconds long sawtoothing L-mode discharges during the 2016 experimental campaign on National Spherical Torus Experiment Upgrade (NSTX-U). Experimental observations through Solid State Neutral Particle Analyzer (SSNPA) and Fast-Ion D-alpha (FIDA) diagnostics show that passing particles within the measured energy range are strongly redistributed from the plasma core to the edge, whereas trapped particles are weakly affected. The effect of sawteeth is clearly seen as a significant reduction of the signal from passing particles inside the sawtooth inversion radius and a corresponding increase at outer radii. Modeling with the standard sawtooth models available in the TRANSP code reproduces the experimental neutron rate drops with the properly chosen model's parameters. However, the FIDA simulation using the plasma profiles and fast ion distribution from the TRANSP simulation does not agree with the experimental measurement. A likely cause of the disagreement between experiments and simulations is that the sawtooth model in TRANSP does not take into account the different effect of sawtooth crash on fast ions with different orbit type and energy. Therefore a more comprehensive and improved model for quantitative simulations needs to be developed to interpret sawtoothing discharges more reliably including the characteristics of fast ion such as energy, toroidal angular momentum and pitch angle that affect the redistribution of fast ions in phase and real spaces. As a first step of the development of the improved sawtooth model, simulations using the Hamiltonian guiding center code ORBIT have been carried out. The simulation results confirm the experimental observation that fast ions are redistributed by sawtooth crash both in phase and real space depending on their orbit type and energy. In real space, passing particles in the core region are expelled outside the q=1 surface while trapped particles do not experience significant effects from sawtooth crash. The initial interpretative TRANSP simulation using the so-called kick model based on the ORBIT modeling result shows improvement of fast ion redistribution before and after a sawtooth crash but the neutron rate still has discrepancy compared to the experimental measurement.

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