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Preliminary experimental study of sawtooth control in strong neutral beam heated plasmas on the HL-3 tokamak

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Sawtooth [1] are important for fusion reactors as they can trigger NTMs by generating seed islands and may lead to disruption in high β_N operations, which severely threaten machine safety and must be controlled [2]. The most frequently used method for sawtooth control is auxiliary current drive (CD), among which electron / ion cyclotron current drive (ECCD and ICCD) are more preferable used due to their fixed depositing positions [3][4]. Previous work has developed an advanced technique for robust control of sawtooth called 'sawtooth pacing', which is based on the sawtooth-stabilizing effect of off-axis ECCD or ICCD [5]-[8]. Yet, as the NBI fast ions also have strong stabilizing effects on sawtooth, it is doubtful whether this technique is suitable for future reactors, and it is necessary to investigate the possibility of performing sawtooth pacing control by utilizing the de-stabilizing effect of ECCD or ICCD.

This work presents the preliminary experimental study of controlling sawtooth oscillations by using ECCD to de-stabilize it in plasmas heated by strong neutral beam injection (NBI). The experiments are performed on HL-3, a medium-size tokamak aimed at studying the key burning plasma physics and engineering techniques for fusion reactors. In the experiments, NBI power up to 4 MW from 2 beamlines are injected in the co-I_p direction, which has strong stabilizing effects of sawtooth and significantly lengthen the sawtooth periods as well as raising their amplitude, making them similar to the so-called "monster sawtooth" previously observed on JET. Various ECCD recipes have been tested for controlling sawtooth in these plasmas, including different power, deposition position and current drive fractions. It is observed that off-axis ECCD that drives current in the counter direction to the plasma current has the most significant de-stabilizing effect on sawtooth, which can be seen from the occurrence time of the first sawtooth, its bursting period and amplitude. Preliminary ECCD power modulation experiments are also done to verify the feasibility of sawtooth pacing control in the presence of strong NBI heating. The physical mechanisms of sawtooth pacing control, indications for real-time control, and future possibilities in developing a comprehensive tool for controlling sawtooth are also discussed.

References

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