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Sawtooth-like oscillation in helical plasmas

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One of the critical phenomena that leads to confinement degradation in magnetically confined fusion plasmas is the sawtooth oscillation[1], which causes repeated collapses of plasma pressure. Sawtooth oscillations are observed in tokamaks, but similar phenomena have been observed in Large Helical Device (LHD). Sawtooth-like oscillations appear during the current ramp-up phase[2] and the density decay phase after hydrogen pellet injection[3]. A new phenomenon, different from previously observed sawtooth-like oscillations in onset conditions, has been observed in relatively high-density regions with a high aspect ratio configuration[4]. The phase of the oscillation in the line-averaged electron density signals inverts around the iota=1 resonant rational surface. Additionally, as the amplitude of the radial magnetic field of the m/n=1/1 mode increases, the electron temperature in the core decreases while it increases at the periphery. These characteristics are similar to tokamak sawtooth oscillations. Here, m/n represents the poloidal/toroidal mode numbers, respectively. Moreover, it is found that applying a static external resonant magnetic perturbation (RMP) can affect the onset of the sawtooth-like oscillations.

This study investigates the density and external RMP conditions under which sawtooth-like oscillations occur. Figure 1 shows a typical discharge waveform when the RMP coil current is ramped up. The phase of the m/n=1/1 component of the RMP formed by the RMP coil is in phase with the same mode component of the error field. The RMP coil current starts to increase at a steady rate from 3.0 s. Oscillations are observed in the electron density signal during the hatched period, and they are synchronized with the change in the amplitude of the radial magnetic perturbation of m/n=1/1 mode. As the RMP coil current further increases, the mode amplitude rapidly grows, and the oscillations disappear, suggesting the penetration of the external RMP into the plasma.

Figure 2 shows the density dependence of the RMP coil current where sawtooth-like oscillations are observed. As the density increases, the coil current at the start of the oscillation observation period decreases. On the other hand, the coil current at the end of the observation period does not change significantly. As a result, the range of RMP coil current where oscillations are observed expands with increasing density. The influence of the density on the onset conditions of sawtooth-like oscillations may be due to the increase in beta value, causing the instabilities to become unstable, or it could be due to conditions becoming more favorable for partial penetration of the external RMP, or both.

References
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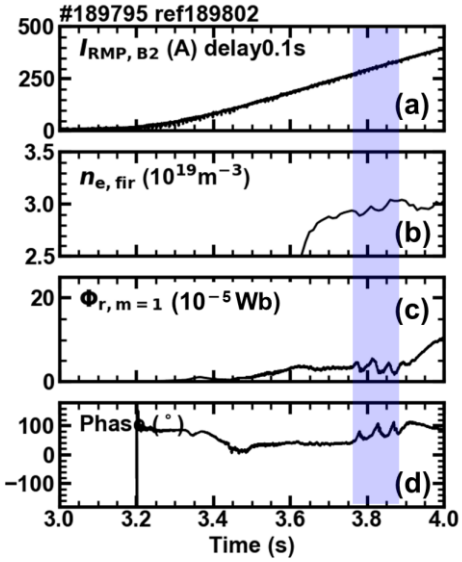

Figure 1. Typical waveform of a ramp-up RMP coil current discharge with density ~ 3×10^{19}m^{-3}. (a) RMP coil current, (b) line-averaged electron density, (c) amplitude, and (d) phase of m=1 mode. The hatched period corresponds to sawtooth-like oscillation.

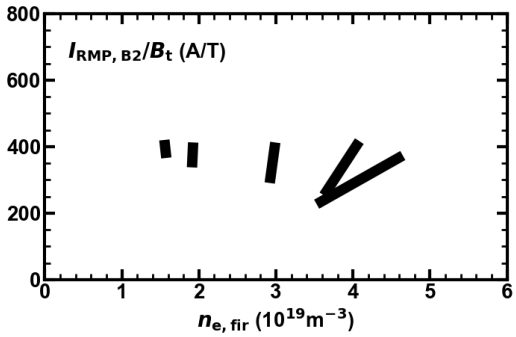

Figure 2. Density dependence of RMP coil current during sawtooth-like oscillation.