§14. Two Types of Sawtooth Crashes Observed in Neutral Beam Heated Plasmas

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Sawtooth oscillations in a tokamak plasma attract much attention because it has a strong impact on plasma confinement near the plasma center and also provides a good example to test various MHD models. Moreover, a heat or density pulse produced by the sawtooth crash plays an important role in perturbative heat and particle transport studies. When the safety factor (q) in the plasma center goes down to less than unity, m=1/n=1 internal kink mode becomes unstable and then induces the sawtooth oscillations through magnetic reconnection process. All of electron cyclotron emission (ECE) or soft X-ray (SX-) signals inside q=1 surface suddenly drop after the sawtooth crash, which is called as "core crash". Recently, off-axis sawteeth are observed in negative magnetic shear configuration in TFTR, where the m=2/n=1 mode appears before and after the crash. The sawteeth are produced through double-tearing magnetic reconnection process. In the off-axis sawteeth, both "core crash" and "annular crash" are observed. For these reasons much attention are paid to the sawteeth also in helical plasmas. We report sawtooth oscillations induced by burst-like magnetic fluctuations with m=2/n=1 mode structure in CHS[1], where the rotational transform profile is similar to that in negative magnetic shear(q'<0) configuration of a tokamak.

So far, sawtooth oscillations are observed only in low density plasmas (<2.5 x $10^{19}m^{-3}$) with small net plasma current induced by co-injected neutral beams or small ohmic field at lower toroidal field(Bt< 1.2 T). Figure 1 shows large sawteeth which lead to "core crash", that is, the SX-emission coming from the core region inside the relevant rational surface 1/q=1/2 suddenly drops and recovers slowly until the following crash. As shown in Fig.1 the sawtooth oscillations are observed accompanying burst like magnetic fluctuations with m=2/n=1 mode structure. The location of sawtooth inversion in line integrated SX-signals is estimated to be $\rho \sim 0.3$. The location of 1/q=1/2 surface is slightly larger than the inversion radius. The different type of crash is observed in a discharge shown in Fig.2, where the location of sawtooth inversion is $\rho \sim 0.4$. The second crash shown in Fig.2 exhibits a character of "annular crash", because the SX-signals near the 1/q=1/2 rational surface are depressed considerably but the signal near the magnetic axis is kept almost constant across the sawtooth crash. Note that the crash first occurs at $\rho \sim 0.35$ and the crash at the center follows with ~ 0.8 ms time delay. As seen from Figs 1 and 2 successor oscillations of 3-5 kHz are considerably enhanced after the crash, and precursor oscillations are observed for a few cycles just prior to the crash. The observed sawteeth accompanying successor are similar to "compound sawtooth" or "partial sawtooth" reported from several tokamaks. However, the driving mechanisms of these sawteeth in CHS are not clarified yet.

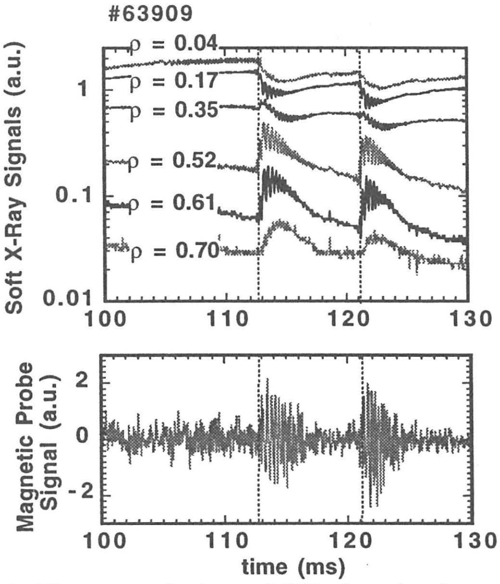

Fig.1 Time evolution of SX-signals along various chord radii normalized by averaged minor radius together with magnetic fluctuations in a sawtoothing plasma .

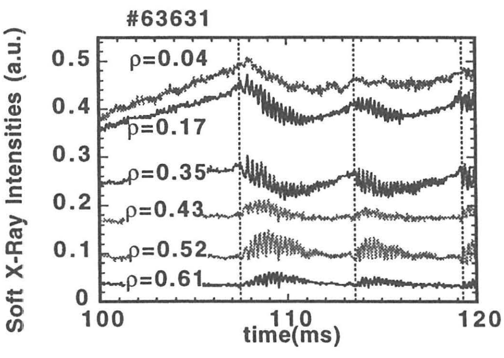

Fig.2 SX-signals indicating the "annular crash", where the crashes occur fairly slowly. The "annular crash" occurs at t~113.5 ms.

References

[1] K. Toi et al., in the 24th EPS Conf. on Plasma Physics and Nuclear Fusion, Berchtesgaden, 1997.