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Study of Edge Plasma Perturbations Induced by Sawtooth Crash on CHS

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Abstract

In the CHS heliotron/torsatron, using a Langmuir probe array, we measured the edge plasma fluctuations during sawtooth oscillations. Ion saturation current, floating potential and their fluctuations are modulated by sawtooth crashes. The fluctuations are enhanced almost similarly from low frequency part (f ~ 2 kHz) to high frequency part (f ~ 100 kHz).

Keywords:

sawtooth oscillation, fluctuation level, Langmuir probe array, ion saturation current, compact helical system (CHS)

1. Introduction

Sawtooth oscillation is a typical magnetohydrodynamic (MHD) phenomenon and plays an important role in core plasma confinement. Heat and density pulses produced by a sawtooth crash may provide important information about heat and particle transport in the sense of perturbative transport. It is also known that a major part of the particle and heat transport in edge plasma is due to the transport driven by fluctuations [1,2]. They are intensively studied in tokamak plasmas. It is important also for helical systems to study plasma transport using heat and density pulses induced by sawtooth crashes. Moreover, these pulses transiently modify temperature and density profiles in the edge plasma region. This may enhance edge turbulence and provide important information on edge plasma transport [3]. In the CHS heliotron/torsatron, sawtooth oscillations are often observed in neutral beam heated plasmas [4]. The change in edge plasma turbulence induced by sawtooth oscillations is studied in CHS, using a Langmuir probe array which can be inserted beyond the last closed flux surface (LCFS).

2. Experimental Setup and Results

The Langmuir probe array consists of multiple electrodes for measuring floating potentials ($V_{f1,2,3}$) and ion saturation currents ($I_{is1,2,3}$) arranged in the radial direction. Figure 1 shows a typical time evolution of plasma parameters in a sawtoothing plasma heated by co-injected neutral beams (NBI). As seen from the time trace of the soft X-ray signal of the central chord, the sawtooth oscillations are clearly observed from $t \simeq 110$ ms.

Figure 2 shows an expanded time evolution of $I_{is1,2,3}$ and $V_{f1,2,3}$ during the sawtoothing phase of the discharge shown in Fig.1, together with those obtained in a particular shot with a large sawtooth crash. In Fig.2(a), the soft X-ray (SX) signal intensity at the center chord (I_{sx0}) is modulated by approximately 8 %. In Fig.2(b), I_{sx0} decreases by about 26 % at the first crash, while the following crashes induce the modula-

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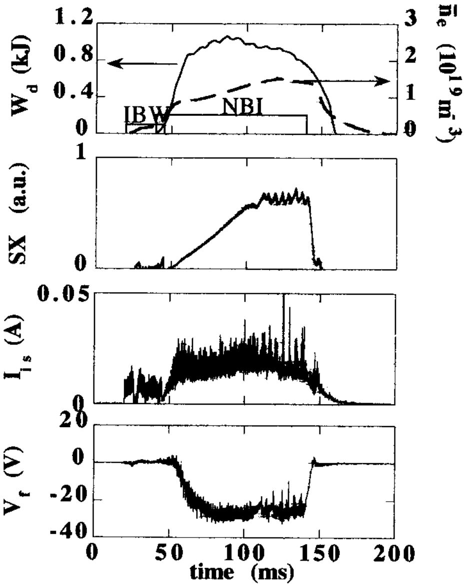

Fig. 1 Time evolution of plasma parameters, soft X-ray signals, ion saturation current and floating potential measured by a Langmuir single probe placed at ρ = 0.95, in a typical sawtoothing discharge.

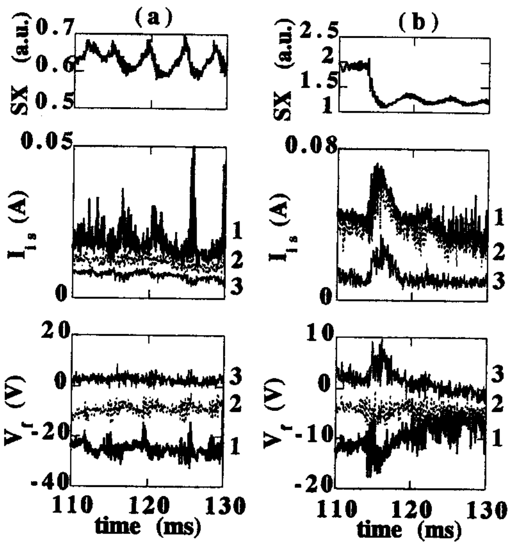

Fig. 2 Expanded time evolution of ion saturation currents $I_{is1,2,3}$ and floating potentials $V_{f1,2,3}$ in the sawtoothing phase, in the plasma shown in Fig.1(a) and a particular shot with a large sawtooth crash (b). The numbers indicated on the right hand side show signals taken by the electrodes placed at ρ = 0.95, 0.97 and 0.98 for case (a), and ρ = 0.99, 1.01 and 1.03 for case (b), respectively.

tion of about 6 %. The discharge conditions of these two cases are following: toroidal magnetic field $B_t \simeq 1.2$ T, line-averaged electron density $\bar{n}_e \simeq 1.5 \times 10^{19}$ m^{-3}, NBI absorbed power $\simeq 0.49$ MW (co-injection) for case (a), $B_t \simeq 1.2$ T, $\bar{n}_e \simeq 2.5 \times 10^{19}$ m^{-3}, NBI absorbed power $\simeq 0.56$ MW (co-injection) + 0.33 MW (counter-injection) for case (b).

In Fig. 2(a), the ion saturation current I_{is1} at ρ = 0.95 begins to increase just after the sawtooth crash,

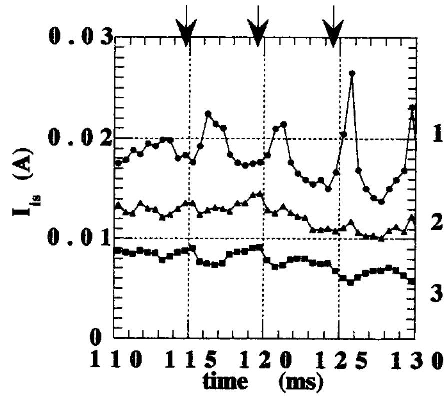

Fig. 3 Quasi-stationary profile of the ion saturation current in the case (a) (Fig. 2(a)), in which the data are averaged over 0.5 ms.

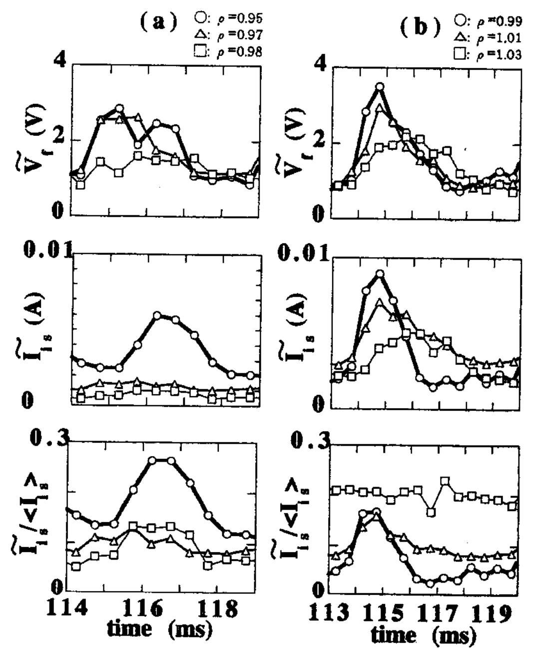

Fig. 4 Modulation of fluctuation levels during one cycle of a sawtooth oscillation in the case (a) and (b) shown in Fig. 2.

but I_{is3} at slightly outer region ($\rho = 0.98$) begins to decrease. This fact is more obvious in the time evolution of the ion saturation current of quasi-stationary component averaged over 0.5 ms at three radial positions (Fig. 3) where vertical arrows indicate the crash time.

Figure 4 shows time evolutions of the fluctuation level of V_f and I_{is} ($\widetilde{V_f}$, $\widetilde{I_{is}}$ respectively), and relative fluctuation level $\widetilde{I_{is}}/\langle I_{is}\rangle$ during one cycle of a sawtooth oscillation. In this figure, the root mean square of fluctuating components of $f \geq 2$ kHz (A) are estimated, as $\tilde{A} = \langle (A - \langle A \rangle)^2 \rangle^{1/2}$, where A is the raw data acquired every 2 μs and $\langle A \rangle$ is the time average over 0.5 ms. The fluctuation level is clearly modulated by a sawtooth crash. The similar behavior is observed in relatively higher frequency components with $f \geq 90$ kHz. The modulation of $\widetilde{V_f}$ and $\widetilde{I_{is}}$ due to the sawtooth crash rapidly decays toward LCFS. On the contrary, the large sawtooth crash shown in Fig. 2(b) induces large modulation of these fluctuation levels even outside LCFS. The increase in fluctuation levels might be caused by the change in equilibrium profile of electron density near the edge, that is, the change in the gradient (*cf.* Fig. 3). These characteristics of propagation and radial profiles of fluctuation level and equilibrium parameters will give us important information about edge plasma transport.

3. Summary

Edge plasma fluctuations induced by sawtooth oscillations were measured by a Langmuir probe array. The obvious modulation of quasi-stationary component and fluctuation level of I_{is} and V_f was observed. In the sawtoothing discharge with ~8 % modulation of the soft X-ray emission at the center, radial profile of quasi-stationary component of I_{is} is modified complicatedly, that is, the modulation does not necessarily take place in phase as discussed in Fig. 3. Fluctuation levels of different frequency components are similarly modified. Correlation between the change in fluctuation level and the modification of the quasi-stationary density profile associated with a sawtooth crash is required in a future study.

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