Parametric Dependence of Sawtooth Crash Time in EAST Tokamak

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1. Introduction

One of the recuring problems in sawtooth oscillation is the nature of sawtooth crash. Yet, there's no consensus on the explanation of the sawtooth crash time. Generally sawtooth crash time changes under different plasma scenarios, even during the current flat top phase in a single discharge, sawtooth crash time varies in a wide range. To more accurately depict this variation and explain it, the accurate sawtooth crash time should be measured, and the dependence of sawtooth crash time on plasma parameters needs to be investigated. Electron Cyclotron Emission Imaging (ECEI) diagnostic system can provide with two-dimensional(2D) images of electron temperature fluctuation in the core of tokamaks; it has been proved to be a powerful visualization tool for the sawtooth evolution. The ECEI system on Experimental Advanced Superconducting Tokamak (EAST) [1] consists of 384 channels by 24 (vertical) × 16 (horizontal), thus having the capability to observe an area of 22 cm (radial)×48 cm (poloidal). By carefully tuning the frequency of the local oscillator and adjusting the front-end optical system, the observation area of ECEI can be altered to cover almost the whole q~1 surface. A method utilizing this property of ECEI is applied here to estimate sawtooth crash time.

2. Sawtooth crash time estimating method

Theoretically, the moment when $m=n=1$ internal kink mode displacement takes place is seen as the start of sawtooth crash [2], and it's marked as crash ending time when all the heat has run out of the inverse radius.

It is obvious that traditional 1D diagnostic like ECE has difficulties to accurately define the crash time constrained by the limited sampling locations in one dimension. Even using ECE imaging, it is still difficult to provide the crash time simply based on the raw data from single channel. On the one hand, when internal kink mode displacement takes place and the cold island forms, the signal from the central channel of ECEI may not change until the cold island moves across the channel. On the other hand, at the time when the central channel signal arrives at the bottom, some heat are still left between the central channel and the inverse radius. Worse still, the precursor and postcursor modes will further influence the judgement of the starting and ending time of sawtooth crash.

The method has been developed [3] to improve the accuracy to estimate sawtooth crash time. Summing up the electron temperature fluctuations of all the ECEI channels inside the sawtooth inverse radius (denoted by black dashed circle in Fig.1(c)), the time evolution of the total electron temperature fluctuation inside q~1 surface is obtained, shown in Fig.1(a) and Fig.1(b). The time lag between one maximum and its neighbour minimum is regarded as sawtooth crash time; and the difference between the maximum value and minimum value of total fluctuation is defined as 'heat flux' here.

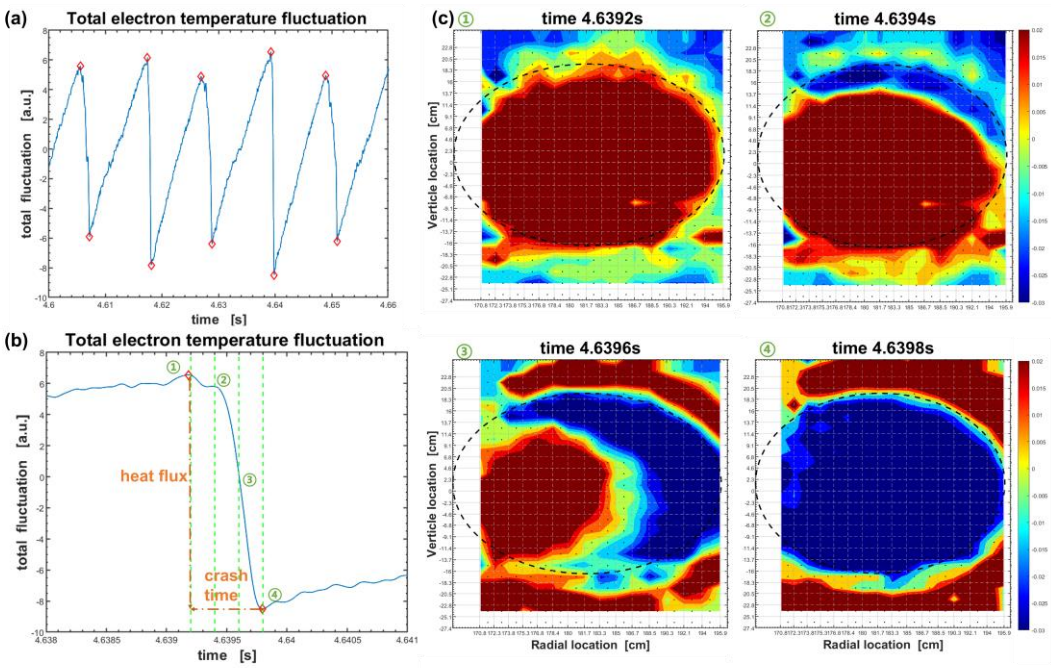

Fig.1 *total temperature fluctuation and ECEI plots of each time point*

The Fig.1(a) and Fig.1(b) shows the total electron temperature fluctuation, as well as the locating of starting time points and ending time points (denoted by red diamonds) for each of sawtooth crash events.

Fig.1 (c) shows ECEI figures corresponding to dashed green lines in Fig.1 (b) who shows the detail of one crash event. It's clearly shown that the moment when total fluctuation begins to collapse is in accordance with the time when the hot core has just shown a little displacement (Fig.1(c)②). The mid phase of the crashing total fluctuation corresponds to the period when the cold island is rapidly growing (Fig.1(c)③). When the total fluctuation drops to the bottom, the cold island occupies the whole region inside the inverse radius (Fig.1(c)④)).

This method is compared with *core-displacement-tracing* method which was used in sawtooth crash investigation on ASDEX-U [4]. That method traces the movement of the hot core and projects the core movement to radial direction in flux coordinate. Utilizing core-movement-tracing method, radial velocity of the core could be derived and used to characterize the reconnection rate.

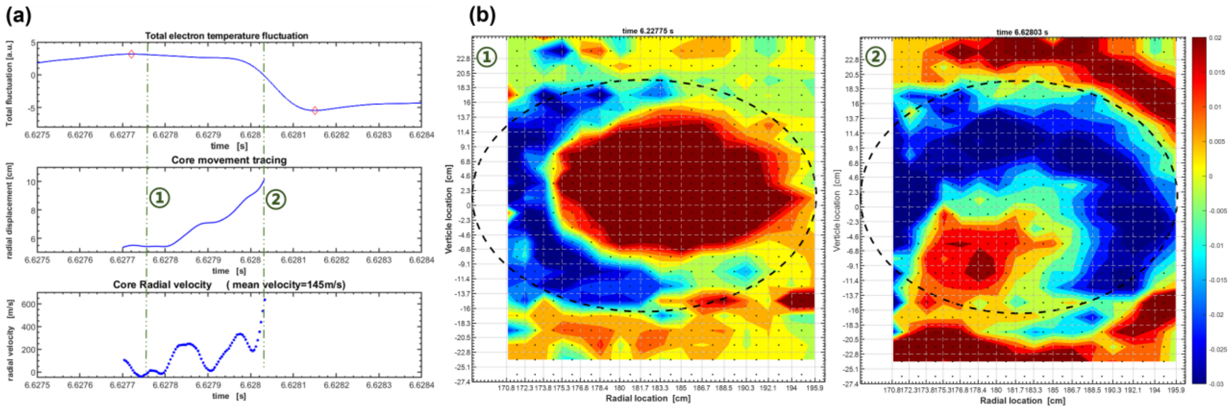

Fig.2 *Comparison of two methods*

As seen in Fig.2, minor drop of total temperature fluctuation corresponds to small core radial velocity. Fast collapse of the total fluctuation corresponds to larger radial velocity. The mean value of radial velocity is calculated to be 145m/s here.

3. Preliminary statistical analyzation of sawtooth crash time

Crash times of hundreds of sawtooth events in EAST discharges #42977, #42978 and #42982 are estimated. The obtained crash time varies from 0.3ms to 2.8ms.

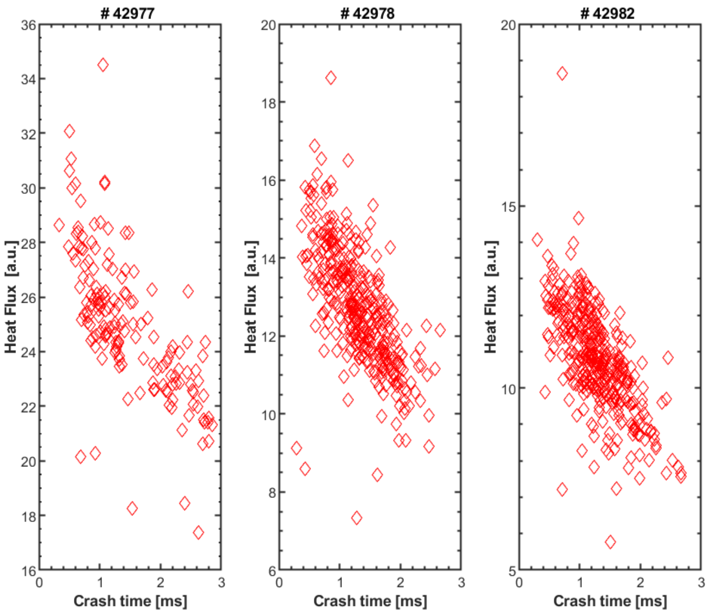

Fig.3 *relation of heat flux and sawtooth crash time*

In the previous study [3], the negative correlation of sawtooth time and heat flux was found in an ohmic discharge. The similar relation is found again this time, shown in Fig. 3. This time the relation in found not only in ohmic discharges (#42978 #42982), but also in the discharge with ICRH (Ion Cyclotron Emission Heating) (#42977). This relation indicates that there may be pressure driven Magnetohydrodynamics (MHD) instability accelerating sawtooth crash.

In the investigation of ohmic discharge #63526 in EAST, it is observed that the sawtooth crash time is getting shorter with decreasing n_e and increasing T_e as shown in Fig.4. The underlying reasons for this dependency is still under investigation.

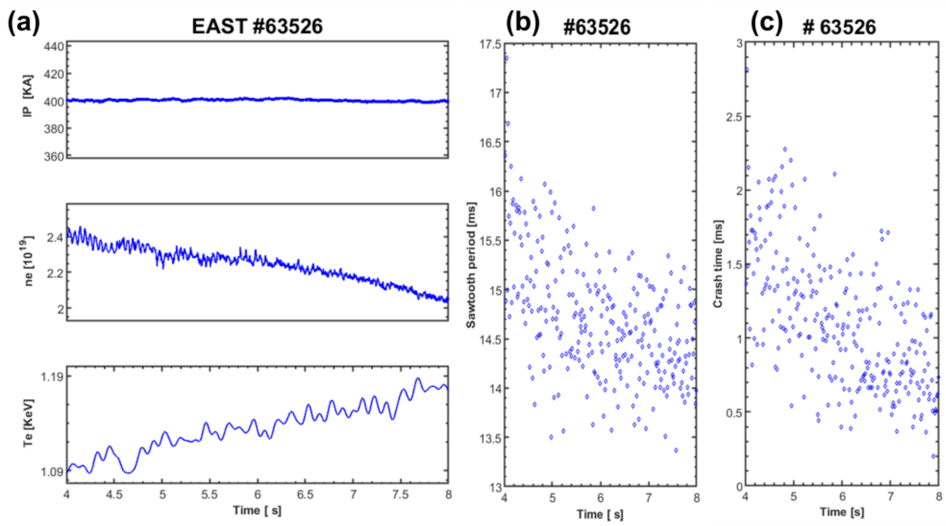

Fig.4 *Observation of shortening sawtooth crash time*

4. Summary

Utilizing the total temperature fluctuation of all the channels inside the inverse radius, sawtooth crash time could be more accurately being estimated. The method is compared with core-displacement-tracing method; their consistency suggests the reliability of the two methods.

Sawtooth crash time of hundreds of crash events in EAST discharges are estimated. The negative correlations of heat flux and sawtooth crash time are found in more discharges in EAST. This indicates that sawtooth crash events may be accelerated by pressure driven MHD instabilities. In another discharge #63526, it is observed that during flat-top phase**,** the sawtooth crash time is becoming shorter. The underlying reason of this phenomenon is under investigations.

References

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