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Study of the snake oscillation phenomenon on HT-7 tokamak

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“Snakelike oscillation” phenomenon has been frequently observed by the soft x-ray camera on HT-7 tokamak in the ohmic plasma, ion Bernstein wave (IBW) heated plasma, low hybrid current drive (LHCD) plasma, D_2 pellet-fuelled ohmic and IBW heated plasma. Some different characteristics from those reported on other machines like JET and Tore Supra etc [1-3] have been found. In this paper, behaviors of the pellet-induced snakes and the spontaneous snakes have been presented and discussed.

1. The pellet-induced snake oscillation in the HT-7 ohmic plasma

Pellet fuelled discharges do not always produce snakes. In the typical operation region on HT-7, snake oscillations occur commonly at a condition of the moderately low density, in which suitably large pellet can penetrate considerably deep into the plasma and cross beyond the q=1 surface with a large global temperature decrease (from the level of keV to that of tens of eV), while the plasma can suffer such large density and temperature perturbation without causing a major disruption or quench. Not all of the produced snakes have long lifetimes. Many snakes are of shot lifetimes, persist for only one cycle of a sawtooth period (a few milliseconds), and then are destroyed by a large sawtooth collapse or a minor current disruption. In the sawtooth-free and MHD-free target plasma, series of the sawtooth-like collapses have been induced by the pellet injection, long lifetime snake oscillation may occur after the first sawtooth collapse. The longest snake persists and survives ten sawtooth collapses with a lifetime of 53.7ms more than three times of the particle confinement time τ_P. The snake excursion radius is always smaller than the sawtooth inversion radius (the radius of the q=1 surface). In the sawtoothing target plasma, series of sawtooth-like collapses have also been induced by the pellet injection, the snake oscillation does not occur after the first sawtooth collapse but after several sawtooth collapses, persists only few cycles and then terminated by a following large sawtooth collapse or a minor current disruption.

Fig.1 shows the time evolution of a typical positive snake with a lifetime of 38.9ms more than two times of τ_P in a sawtooth-free and MHD-free discharge, which is corresponding to No.5 and No.6 snake cycles in Fig.2. Following the sawtooth collapse at 277.5ms, the snake oscillation appears intermittently, persists eight cycles and survives seven big sawtooth collapses until terminates before a minor current disruption. The snake develops in a region of the greatly enhanced SXR radiation in the region of -0.22a to 0.47a (up to a factor of 3-4) over its surrounding plasma, an enhanced density (up to a factor of 2-3) and a depressed temperature (≤ 5%) compared with those of pre-injection state. Each sawtooth is well corresponding to a snake cycle. The rotation frequency (defined as the inversion of the rotation period during the snake cycle) and excursion radius of the snake, as shown in Fig.2, are affected obviously by the sawtooth collapse. Typical snake cycle evolves through a continuous process of sudden startup, slowdown and speedup until locking or starting next cycle. Over the whole snake oscillation, the snake evolves with trends of increasing the rotation frequency, and enlarging the horizontal scope mainly in the low field side with a shape of the sinusoidal envelope, and with a slow outward movement of the snake centroid before sudden termination, which is consistent with the gradually outward shift of the horizontal displacement $\triangle_{//}$, but without apparent sign of decaying. It suggests that although sawtooth collapses cause an enhancing loss of energy and particles to the outer region from the plasma core, the snake rotating can still be maintained by the confined ablating particles and their energy.

It is more interesting that the No.8 snake cycle does not accompany a detectable sawtooth collapse, but a sudden decrease of the core temperature from 313ms is found. This precursor of the temperature variation probably implies that a variation of the current density profile is responsible for the disappearance of the q=1 surface and is associated with following termination of the snake oscillation. The cause for the temperature variation is unclear and probably associated with variations of the plasma pressure. No direct evidence shows that it comes from the central impurity accumulation.

Normal MHD activity occurs and evolves corresponding to the snake oscillation since the snake is produced. Mirnov oscillation with a dominant m=3 in the magnetic pick-up coil reaches the maximum amplitude before the snake termination. In some cases, an m=2 mode which grows to a large amplitude eventually couples with the snake. Most snakes rotate in the ion drift direction, occasionally in the initial phase of the snake cycles, a reversal rotation in the direction of the electron drift can be observed, but only lasts a cycle, and then the snake rotates in the ion drift direction during all following cycles.

2. Spontaneous snake oscillation in the HT-7 plasma

Most spontaneous snakes persist continuously for a period about 1-2 times of τ_P and terminate silently without obvious variations of the plasma parameters like a minor current disruption. Some snakes can persist intermittently with a comparable long lifetime to that of the pellet-induced snake. The spontaneous snakes usually have a somewhat larger excursion of -0.18a to 0.54a than that of the pellet-induced snakes. They are not characterized by an apparent enhancement of the SXR emission over its surrounding plasma and are of a visible decaying in the SXR intensity during the snake development. The spontaneous snakes can only survive a small sawtooth collapse and are easily destroyed by a big sawtooth collapse. The common features of the spontaneous snakes are sawtooth-free or the suppression of the sawtooth activity and a rising peaking profile of the SXR emission before the creation of the snake, in which the SXR profile is outstanding peaking for the cases of the ohmic and IBW heated plasmas, and is moderate peaking for the LHCD plasma. It is thought to be of a high impurity concentration hence a high electrical resistivity in the central region of the plasma. Fig.3 shows the frequency evolution of the spontaneous snake in the IBW heated plasma, which is very different from that of the pellet-induced snake shown in Fig.2. Except that the spontaneous snakes in the ICRF heated plasma always rotate in the direction of the electron drift, others always rotate in the ion drift direction, and no reversal direction during the way has been observed. Before the creation of the spontaneous snake, a MHD activity is frequently present before the first sawtooth, which always rotates in the direction of the electron drift, seems to play an important role in the formation of the first sawtooth collapse and the following snake oscillation.

Acknowledgments

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References

1. A. Weller, A. D. Cheetham, A.W. Edwards, et al., Phy. Rev. Lett. 59(20), 2303, 1987
2. R.D. Gill, A. W. Edwards, D. Pasili, A.Weller, Nucl. Fusion 32(5) (1992) 723.
3. A. –L. Pecquet, P. Cristofani, M. Mattioli, et al., Nucl. Fusion 37(4) (1997) 451.

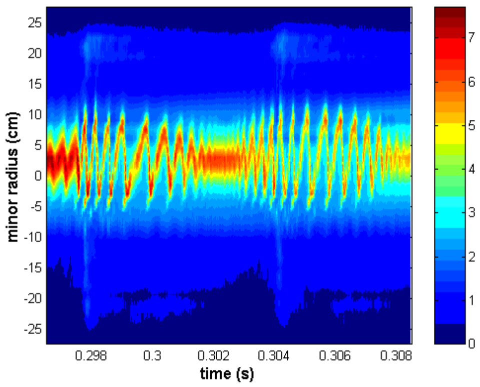

Fig.1 The time evolution of the pellet-induced snake on the SXR radiation signal

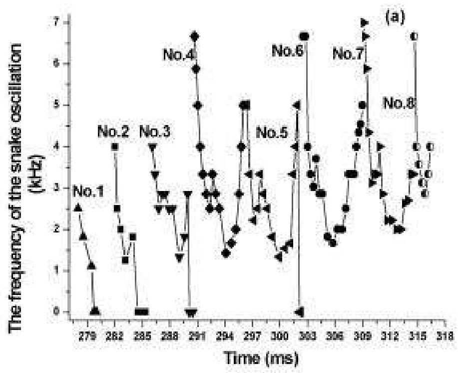

Fig.2a The frequency evolution of the pellet-induced snake oscillation

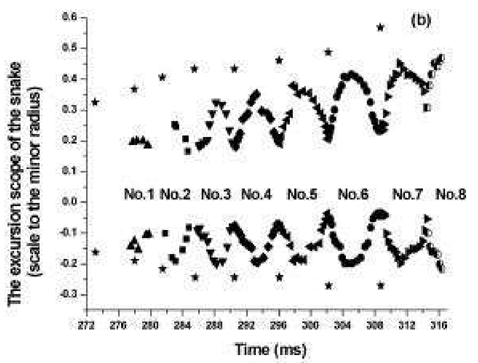

Fig.2b The excursion radius evolution of the pellet-induced snake (solid star symbols represent the inversion radius and the collapse time of the sawtooth)

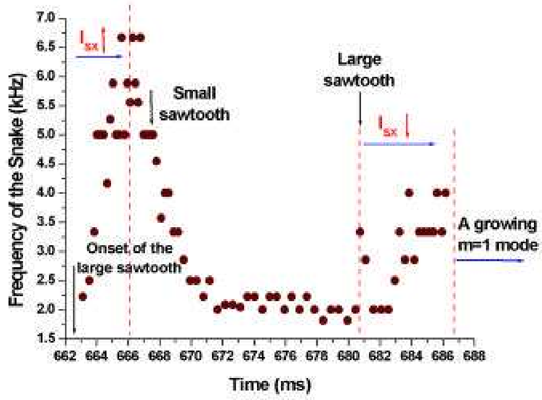

Fig.3 The frequency evolution of the spontaneous snake in the IBW heated plasma