§7. Nonlinear Dynamics of an ELM Crash in Spherical Tokamak

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ELMs are often observed in the H-mode operations of ST experiments, as well as the conventional large tokamaks. To control the ELMs is one of the most important issues for the sustainment of a good confinement state. Experimentally, several characteristic structures of ELMs are observed in the middle-sized ST devices such as MAST and NSTX. In this paper, we propose a modeling of an ELM crash with a consecutive scenario which is initiated by the spontaneous growth of the ballooning mode instability, comparing with the experimental observations. Furthermore, more realistic situations are examined by using the drift model.

Firstly, a nonlinear MHD simulation is executed in a three-dimensional full toroidal geometry[1]. The initial condition is given by a reconstructed equilibrium from the NSTX, where β_0=28%, q_0=0.89, and A=1.4. The system is linearly stable for the ideal modes, but weakly unstable for the resistive ballooning modes. the simulation result shows a two-step relaxation process induced by the intermediate-n ballooning instability followed by the m/n=1/1 sawtooth crash, where m and n are the poloidal and toroidal mode number, respectively. Especially, thin and elongated balloons are formed along the field lines on the plasma surface on the nonlinear phase. They eventually turn into bubbles, and are isolated from the core plasma, as shown in Fig.1. This behavior well agrees with the experimental observation by using fast camera images in MAST. After the eruption of the balloons, the poloidal pressure profile becomes a peaked one from a broader one in the central region due to the convection motions of the ballooning modes. The q profile also goes below 1 at the center. These profile changes can induce another instability, i. e., the m/n=1/1 kink mode. The system crashes once again due to the 1/1 mode, and recovers a broader profile, just like the well-known sawtooth crashes. During this process, one can see a characteristic non-axisymmetric structure with a large n=1 component, which is also clearly observed in the experiments.

Thus, our simulation result explains several characteristic features of the so-called type-I ELM:(1)relation to the ballooning instability (2)intermediate-n precursors (3)low-n structure on the crash (4)formation and separation of the filament (5)considerable amount of convective loss. As for the time scale, the simulation result is consistent with the experimental ELM rise times of the order of ~100 μsec.

Furthermore, we have examined the drift model simulation to follow the dynamics under more realistic situations[2]. Including the lowest order modification of the ion diamagnetic drift effect, we introduce the flow velocity variable as the sum of the conventional MHD velocity and the ion diamagnetic drift velocity. The result shows that the mode structures rotate both toroidally and poloidally. Under this situation, the higher-n modes are linearly stabilized, whereas the lower-n modes remain unstable. This changes the linear toroidal mode structures drastically. On the other hand, it is found that the nonlinear dynamics is not so affected by those modifications, i. e., the filament separation from the core can take place universally for the drift model case as well as the MHD case (see Fig.2), despite a remarkable changes in the nonlinear flow patterns on the filaments due to the diamagnetic rotation.

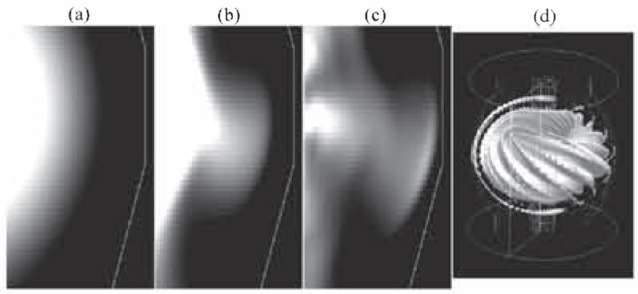

Fig.1 (a)-(c) Formation of the plasma balloons and separation from the core. (d) Formation of the filamentary structure.

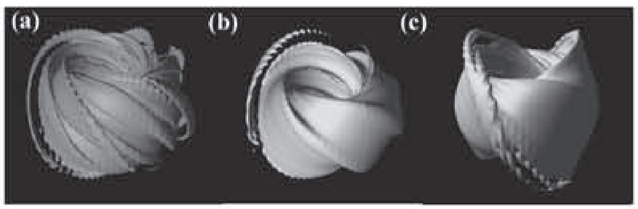

Fig.2 Universally formed plasma filaments for the drift model cases. Different control parameters for the diamagnetic drift term are used for each cases ((a)-(c)).

Reference
1) N. Mizuguchi, et al., IEEJ Trans. FM **125**, (2005) 934
2) R. Khan, et al., to appear in J. Plasma Phys. (2006)