§4. Nonlinear Simulation of Edge-Localized Mode in Spherical Tokamak

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The edge-localized mode(ELM) is an instability which is observed near the edge of the torus plasma. Experimentally, ELMs are often observed in some H-mode operations and are thought to have an important role the for advanced confinement regime. However, detailed mechanisms of ELM remain to be solved. In spherical tokamak, such as the Mega-Amp Spherical Tokamak (MAST) device, the overall structure of the ELM activity has been observed in detail by using cameras. The camera image clearly shows a belt-like structures along the magnetic field. These structures are called "filaments" or "blobs". Detailed analysis shows that a plasmoid is separated radially from the main part of the torus. Such filament structures are also observed in the National Spherical Torus Experiment(NSTX). We have executed a numerical simulation which is based on the nonlinear resistive magnetohydrodynamic(MHD) model to reveal such mechanisms on an ELM.

The initial condition of the simulation is given by the reconstructed equilibrium of the NSTX plasma, where the β_0=28%, q_0=0.89, and A=1.4. The initial equilibrium is unstable for some ballooning modes under the resistive MHD regime. The three-dimensional structure of this instability is shown in Fig.1. The shape of the plasma surface is drawn by the light gray iso-pressure contour. One can see that the plasma surface is wrinkled, and that several numbers of the ridges which are equivalent to the most dominant toroidal mode number emerge along the surrounding magnetic field. Since the "balloon" of the plasma pressure rapidly distorts the cross-field component of the magnetic field, current filaments are partly induced along the magnetic field, as shown together in Fig.1 by the dark gray iso-pressure contour. These structures well agree with the experimental observations of MAST. It should be also noted that the number of the filaments is reduced compared to the ballooning mode number. This can be explained by the coexistence of the multiple modes.

In Fig.2, the temporal changes in the pressure profile in a poloidal cross-section are shown. At the beginning of the nonlinear stage(Fig.2(b)), the plasma surface is wrinkled compared to the initial state(Fig.2(a)) due to the growth of the ballooning mode. Then the balloons grow rapidly. In particular, one of the balloons, the outermost one in the figure, changes largely in the shape. The leg of the balloon gets thin gradually(Fig.2(c)). Finally, the head of the balloon is separated from the bulk(Fig.2(d)) plasma, as indicated by the arrow in Fig.2(d). This separation process is clearly observed experimentally in MAST. By this simulation, it is revealed that such a formation of the filament structures and the separation phenomenon on ELMs can occur as a result of only the nonlinear MHD process.

The simulation results described above show some good agreement with the experimental observations. If we list the agreements, (1)the blobs are formed along the magnetic field lines, (2)the amplitude of the blobs appears nonuniformly in toroidal directions, and (3)a plasmoid is ejected radially from the ridge of the blobs. Though these comparisons with our present simple model may be still rough, they provide us with valuable information to better understanding of such a complicated phenomenon.

Fig.1. Three-dimensional structure of the filaments.

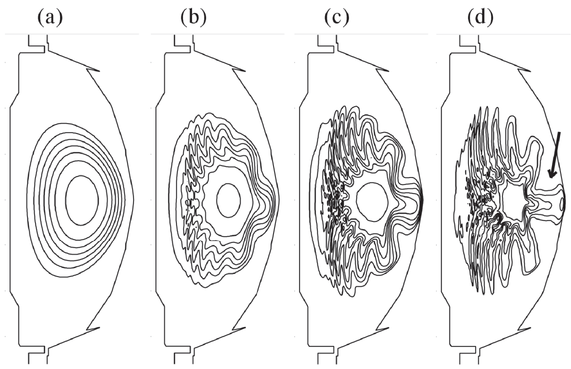

Fig.2. Time development of the poloidal pressure profile.

Reference

1) Mizuguchi,N., Khan,R., Hayashi,T., IEEJ Trans. A **125**(11), (2005) in press.