§4. Simulation of Internal Reconnection Event in Spherical Tokamak

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We have executed 3-D MHD simulations in a full torus geometry to investigate the physical mechanisms of the IRE (Internal Reconnection Event), which has been observed in spherical tokamak (ST) experiments such as START and CDX-U.

The simulation results of the time evolution of perturbations applied to an initial ST equilibrium, where the aspect ratio A=1.35, the elongation κ=1.6, the central beta β_0=48%, and the central safety factor q_0=0.91, has successfully reproduced several main properties of IRE such as, (1) the rapid fall of the central plasma pressure, (2) the rapid transport of the heat from the core to the edge, (3) the rapid increase of the net toroidal current, (4) the precursors of low m and n MHD activities, (5) the increase in the elongation of the poloidal cross section. Analyzing the simulation results in detail, we have obtained a hypothetical sequence of the physical mechanisms for IRE:

(1) Multiple linear eigenmodes on the q=1 rational surface grow simultaneously. In particular, low m/n modes, such as 1/1 and 2/2 modes, have large growth rates. Most of the modes are categorized into the pressure-driven interchange mode. The thermal energy of the plasma is transformed into the magnetic energy as the instabilities grow.

(2) In the weakly nonlinear stage of the growth, some of the dominant modes interact each other. Especially, it is noted that the phase of the n=1 mode is spontaneously aligned with that of the n=2 mode in toroidal direction. Then a bulge-like deformation at a local region in the toroidal direction is formed as the result of the superposition of the nonlinear modes (Fig.1(a)).

(3) In the highly nonlinear stage, a current sheet structure is formed on the periphery of the torus at the local region where the bulge is pressed against the external magnetic field, and a magnetic reconnection is induced between the field lines in the separatrix and the external opened ones (Fig1(b)), and the increased magnetic energy is released. The plasma pressure is rapidly transported out of the torus along the field lines reconnected, and makes the overall shape of the torus elongated vertically (Fig1(c)).

This model described above is a brand-new one for dealing with a relaxation phenomena in tori, and will give some meaningful suggestions not only in the control of ST plasma, but also in finding general rules of plasma relaxation phenomena which are induced by pressure-driven instabilities.

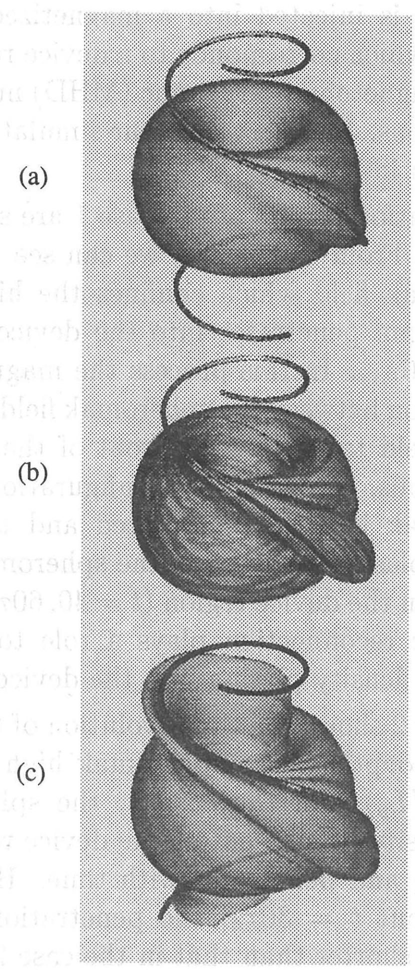

Fig.1 Nonlinear evolution of plasma pressure and a certain magnetic field line at time (a)t=190τ_A,(b)t=197τ_A,and (c)t=213τ_A.