§2. Nonlinear MHD Simulation of Collapse Event in LHD

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To model the large-scale collapse event termed CDC (core density collapse) observed in the vicinity of the marginally stable condition for the outward-shifted LHD operations, we have executed nonlinear magnetohydrodynamic(MHD) simulations in a realistic LHD configuration with a large pressure gradient. The simulation results reproduce the basic characteristics of the experimental observation on the CDC events in LHD. The spatio-temporal development of the core pressure structure is investigated in detail[1).
The initial condition of the simulation is given by a numerical equilibrium obtained by using the HINT2 code. It roughly models the LHD plasma for the time just prior to a CDC, in which the pressure profile has a large gradient with the central and volume-averaged beta $\beta_0 = 6.6\%$ and $< \beta >= 1.8\%$. The simulation code used in this study is the non-axisymmetric version of the three-dimensional finite difference code (MEGA-D) developed at NIFS, in which the time development of the nonlinear resistive compressive MHD equations are solved explicitly.
The simulation result shows the linear growth of the resistive instability which has the nature of the ballooning mode under the assumption of large value of the resistivity. The growth of the modes are saturated soon, and the system experiences the energy relaxation three times in about $500\tau_A$ (< 1 msec). It should be noted that the linear mode structures are localized in the edge region, whereas the core pressure rapidly falls as the system reaches the finally relaxed state. The co-existence of the edge perturbation and the core collapse is comparable to the experimental observations. The lost pressure forms a wider tail in the peripheral region (see Fig. 1).
This result shows that the core collapse can be induced only by the convective process rather than the conductive one. The core pressure is remarkably reduced at $t = 550\tau_A$, while it had withstood the disturbance during the former period. The most salient feature on that period is the disordering of the magnetic field structure(see Fig. 2). The system keeps well the structure of the nested flux surfaces in the core region in the beginning, whereas they abruptly diminish at around $t = 300\tau_A$. The simulation result shows a deformation of the pressure profile due to the instabilities. In Fig. 2(b), one can find that the magnetiv surfaces diminish in the core region, implying that the plasma flows are driven by the pressure gradient along the magnetic field lines which might be formed by the reconnections of the field lines. Thus, the core collapse can be caused by the disturbance of the magnetic field due to the growth of the edge instabilities.
In summary, we have modeled the nonlinear dynamics of the collapse event like CDC in LHD by means of the nonlinear MHD simulation. Comparative analysis with experimental operation parameters is our ongoing study.

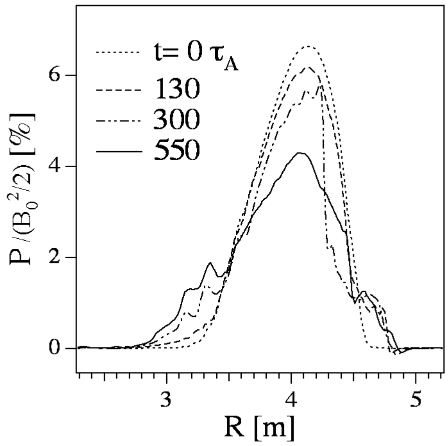

Fig. 1: Time development of the radial pressure profile on the horizontally elongated equator.

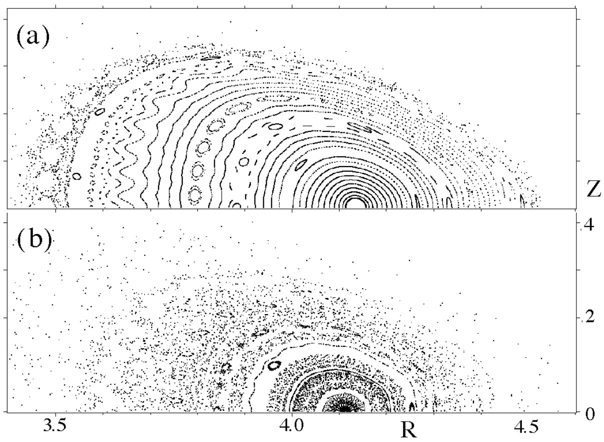

Fig. 2: Temporal change in the magnetic structure. Puncture plots of the magnetic field for (a) t=0 and (b) 300 τ_A are plotted.

1) N. Mizuguchi, Y. Suzuki, and N. Ohyabu, "Nonlinear dynamics of a collapse phenomenon in heliotron plasma with large pressure gradient", Nuclear Fusion , (2009) vol.49 095023