

§9. Nonlinear Modeling of Core Density Collapse

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We have executed nonlinear magnetohydrodynamic (MHD) simulations in a heliotron-type configuration with a large pressure gradient to reveal the nonlinear dynamics of collapse phenomena of plasma. The simulation results reproduce the basic characteristics of the experimental observation on the so-called core density collapse (CDC) events in the Large Helical Device (LHD) plasma with a large pressure gradient which is achieved by the existence of the internal diffusion barrier (IDB). The spatio-temporal development of the core pressure structure is investigated in detail¹⁾.

The initial condition of the simulation is given by a numerical equilibrium obtained by using the HINT2 code²⁾. It roughly models the IDB-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 $\langle \beta \rangle = 1.8\%$. The simulation code used in this study is the non-axisymmetric version of the three-dimensional finite difference code 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 somewhat exaggerated 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.

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 around $t = 350\tau_A$, 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. The system keeps well the structure of the nested flux surfaces in the core region in the former stage ($t < 330\tau_A$), whereas they abruptly diminish at around $t = 335\tau_A$. The simulation result shows a deformation of the pressure profile due to the instabilities. On the highly deformed stage, a lot of fingers are formed in the edge region. The rate of the pressure reduction estimated by the energy flux $|p\mathbf{V}|$, where p and \mathbf{V} are the pressure and the flow velocity, is also plotted in Fig. 1(a) by the line contours, which are mainly located on the

root of the fingers. The neighboring magnetic structure is shown in Fig. 1(b). The magnetic flux surfaces are hard to find except for the region between some islands or their ruins. In Fig. 1(b), one can find a couple of clear surfaces at $R = 4.24\text{m}$ and 4.30m on the equator ($Z = 0$), putting the $\iota = 2/3, 5/8$, and $4/7$ islands between them, and that the spots of the pressure drop exist in the disordered region. Other analyses support that these flows are almost parallel to the magnetic field, implying that the flows are driven by the pressure gradient along the magnetic field lines which might be formed by the reconstructions 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.

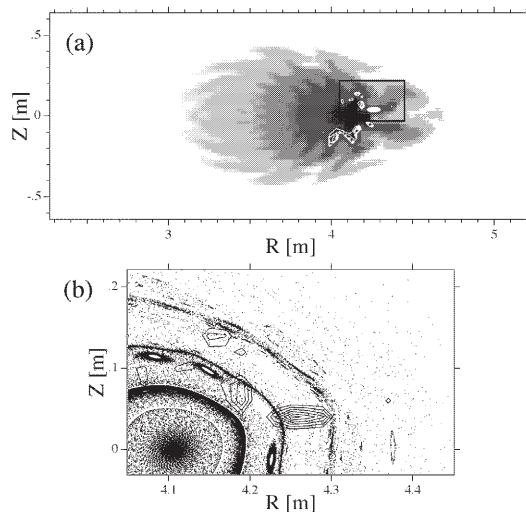


Fig. 1: FIG.1 (a)Structure of the pressure (shade contour) on a horizontally elongated poloidal cross section, and (b)puncture plot of magnetic field drawn in the box on (a) at $t = 335\tau_A$ with energy flux contours (by lines).

In summary, we have modeled the nonlinear dynamics of the Core Density Collapse from the point of view of the MHD instability. Comparative analysis with experimental operation parameters would be the next step of this study.

- 1) N. Mizuguchi et al., Plasma Fusion Res. **3** (2008) S1034 .
- 2) Y. Suzuki et al., Nucl. Fusion **46** (2006) L19.