

§3. Numerical Simulation of Internal Reconnection Event in Spherical Tokamak

Mizuguchi, N. (Grad. Univ. Advanced Studies),
Hayashi, T., Sato, T.

An Internal Reconnection Event (IRE) is the most noticeable relaxation phenomenon observed on spherical tokamaks. It is characterized by a rapid fall in the SXR signal and a spike on the net plasma current trace. This study aims to clarify the physical mechanisms of the IRE by using a nonlinear MHD simulation. The simulation is executed in a full-torus geometry with an open external magnetic field. The parameters used in the calculation correspond to the operation regime of the START experiments at Culham, that is, the aspect ratio is 1.35, the elongation is 1.6, the central beta is 48%, and the central safety factor is 0.91. The simulation results described here successfully reproduce the key features of the IRE.

Figure 1 shows the time development of the pressure profile. A toroidally localized deformation appears near the outermost surface of plasma at $t = 200 \tau_A$ (Fig.1(c)) as a result of the nonlinear growth of the MHD instability. The instability is found to be categorized into a pressure-driven interchange mode. The spectral analysis shows that the instability consists of multiple number of low m/n modes such as $1/1$ and $2/2$ modes. The precursory activity appears as the superposition of these modes shown in Fig. 1(b). The central pressure falls in a short time scale of around $100 \tau_A$ in consequence of the convective transport caused by the mode activities. The localized deformation generates a current sheet on the outermost surface, which induces a magnetic reconnection between the internal and the external magnetic fields. Along the field lines connected directly among the fields, a "path" of plasma away from the core is opened. The plasma blows out to the top and the bottom of the boundary twisting the whole shape of the plasma helically almost along the magnetic field (observed in Fig.1(d) as an extending fraction of the pressure to the top and the bottom like a horn). Expelling a part of thermal energy in such mechanism described above, the system tends to be a stable one. Almost axisymmetric configuration appears again in Fig. 1(e). However, it is not completely stable, so that another kind of instability begins to grow after that. The secondary excited instability has different characteristics from the first one. The most dominant mode for the second instability is $m/n = 2/1$ one shown in Fig.1(f), which seems to be a kind of current-driven mode. A remarkable increase in the net toroidal current accompanies the growth.

The simulation results are carefully compared with the experimental observations of IREs obtained in the START experiment by courtesy of Drs. A. Sykes and M. Gryaznevich of UKAEA, Culham. There are several points of good agreements among them as follows:

- 1) A rapid thermal quench occurs in a short time scale of around $100 \tau_A$.
- 2) Low m/n activity are observed just before an IRE.
- 3) The heat energy are transported from the central region to the edge on the thermal quench.
- 4) The thermal quench usually proceeds in two steps. The first one is faster than the other.
- 5) The current spike is seen after the thermal quench.
- 6) A characteristic conical shape is formed in the pressure profile in the top and the bottom of torus.
- 7) A toroidally localized helical distortion is seen.
- 8) The axisymmetry of the torus is broken (see Fig. 2). It is vertically elongated in one side, and is radially fatten in the opposite side, which corresponds to the $m/n = 2/1$ distortion.

It is concluded that the pressure-driven instability can actually induce an IRE in the nonlinear time development.

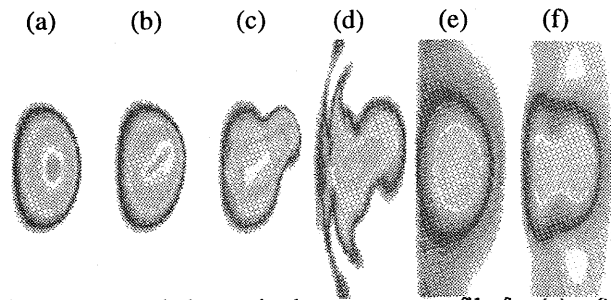


Fig.1 Temporal change in the pressure profile for (a) $t=0$, (b)180, (c)200, (d)250, (e)350, and (f)500 τ_A .

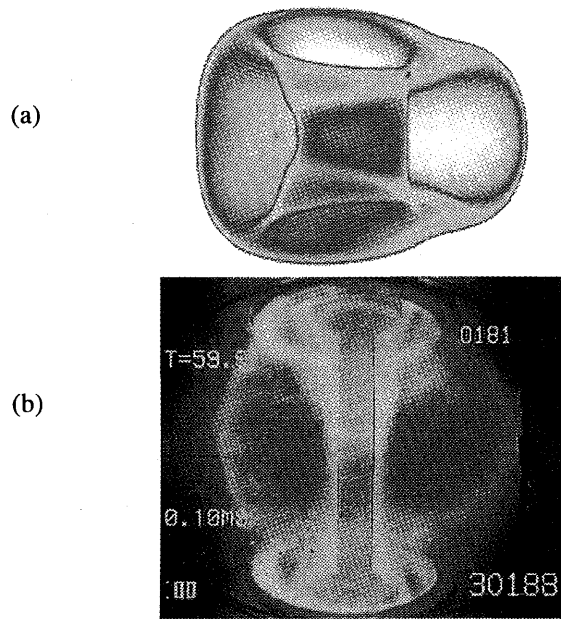


Fig. 2 (a) The reconstructed image for the $m/n=2/1$ distortion from the simulation result by using a volume rendering scheme. (b) CCD camera image of the START spherical tokamak when the IRE is observed by courtesy of Drs. A. Sykes and M. Gryaznevich.