§5. Modeling of Internal Reconnection Event in Spherical Tokamak

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

Nonlinear magnetohydrodynamic(MHD) simulation has been executed in order to reveal the dynamics of the internal reconnection event (IRE) which is observed in spherical tokamak experiments[1]. An IRE is observed as a rapid fall in the soft X-ray signal and an increase in the net toroidal current, together with a drastic deformation in overall shape. However, the physical mechanism of IRE had not been clarified enough yet. The simulation is executed in a full toroidal spherical tokamak geometry including an open external magnetic field region, so that the dynamical behavior of an IRE, such as a large distortion in overall shape, can be appropriately treated. The spontaneous time development of tiny perturbations applied on an initial unstable equilibrium is pursued by a high-accuracy scheme. The simulation results successfully reproduce the key features of IRE in good agreement with experimental observations[2]. An initial equilibrium including a q=1 rational surface causes the growth of MHD instabilities. The dominant linear eigenmodes are found to be a combination of several low-n modes. Especially, the m=2/n=2 and the m=1/n=1 pressure-driven ideal interchange modes grow simultaneously with almost the same large growth rate. As a result of the nonlinear development of such low-n modes, which induce elliptically elongating and shifting convection flows in the poloidal cross section, a large pressure bulge appears on the surface of the torus in a toroidally localized region, where the radial displacements of each mode are positively aligned to each other. The localized deformation generates a current sheet structure near the separatrix, which induces a magnetic reconnection between the internal and external magnetic fields. The reconnected field line links the core region at high pressure and the peripheral region at low pressure, so that a large pressure gradient is formed along the reconnected field line. The confined plasma is rapidly expelled out of the torus due to the flows induced by the pressure gradient. The expelled plasma extends in the periphery, forming a characteristic helically twisted conical layers at the top and the bottom of the torus, which is in good agreement with experimental results observed by using a CCD camera. On the other hand,the plasma pressure at the center of the torus falls into about 40% of that at the initial state in a short time scale of several tens of Alfven transit time,which also agrees well with experiments. After releasing a part of heat energy out of the separatrix, the system is once stabilized with respect to ideal modes. However, another kind of an instability, which has a nature of a resistive mode, is excited. This instability includes an m=2/n=1 component dominantly, and can be destructive compared to the original ideal modes. Due to the growth of this instability, the overall shape of the torus is largely distorted, which agrees with experimental observations, such as the tilting and the axis-asymmetric elongation of the torus. More detailed analyses of the simulation results show several interesting dynamics on pressure-driven relaxation phenomena, such as an almost parallel magnetic reconnection, formation of a tunnel-like convective loss channel due to the magnetic reconnection between the internal and the external fields[3] [see Fig. 1], and spontaneous phase alignment among multiple modes on weakly nonlinear development of pressure-driven instability.

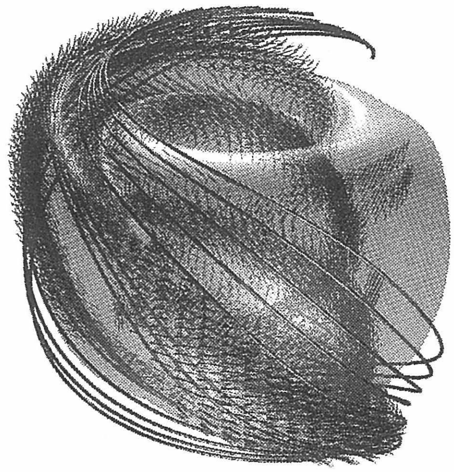

Fig.1 Plasma loss flow (fine arrows) which is formed by a magnetic reconnection between the internal and external fields. Thick lines indicate arbitrary traces of magnetic field lines. Plasma surface is represented a semi-transparent iso-pressure surface.

Reference

1) Hayashi, T. et al. : Nucl. Fusion 40 (2000) 721.
2) Mizuguchi, N. et al. : Phys. Plasmas 7 (2000) 940.
3) Mizuguchi, N. et al :Cont. Plasma Phys. 40 (2000), 316.