## §8. Nonlinear Analysis on Magnetic Perturbation in Periphery of LHD

Matsumoto, Y., Ueda, R., Takado, W., Itagaki, M., Oikawa, S., Ishimaru, K., Kitayama, K. (Hokkaido Univ.),
Watanabe, K.Y., Suzuki, Y., Sato, M., Seki, R.

In the recent campaign of the Large Helical Device (LHD) experiments, the coherent magnetic field fluctuation resonating with $m/n$ = 1/1, 2/3, 3/4 is observed in the peripheral magnetic field region outside the last closed magnetic surface[1]. The purpose of the present study is the analysis of these modes based on the MHD simulation in the LHD.

The nonlinear MHD code based on the real coordinate system has been developed to investigate the magnetic fluctuation in the peripheral region. In this code, the time evolution of the vector potential instead of the magnetic field itself to satisfy div$\boldsymbol{B}$ = 0 condition. In addition, the pseudo-plasma model, in which we assume the high resistivity plasma filled in the vacuum region, is adopted. As the computational techniques, the 4th order finite difference method, the 4th order Runge-Kutta method and the Rational Constrained Interpolation Profile (R-CIP) method[2] are used. To prevent the numerical oscillation, MmB method[3] is also adopted.

The developed code is applied to the LHD plasma, of which equilibrium is calculated by HINT2 code, with β = 2%. For the given initial velocity perturbation, the time evolutions of density, velocity, pressure and magnetic field are calculated. Figure 1 shows the time evolution of the energy. The linear growth and the nonlinear saturation of the perturbation can be seen from Fig. 1.

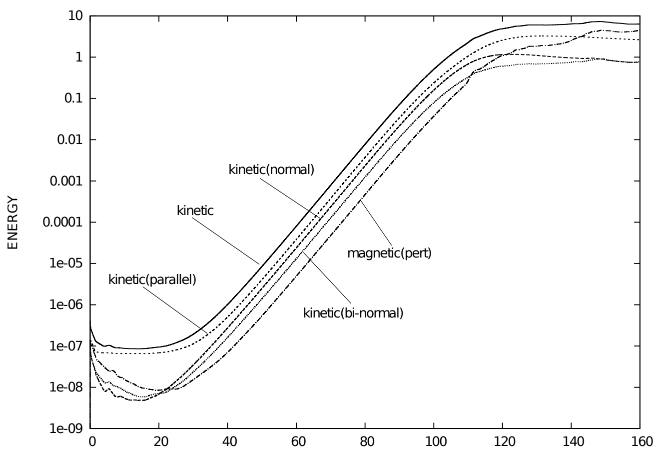


Fig. 1. Time evolution of energy. Kinetic energy (parallel, normal and bi-normal direction), magnetic energy, internal energy and total energy are shown.

In parallel to the above study, we investigate the formation of the magnetic island when the resistive interchange mode is unstable. The analysis is carried out by use of the reduced MHD equations. Solving these equations as the eigen-value problem, some eigenmodes are obtained. Among these eigenmodes, we define the eigenmode with the largest (second largest) growth rate as the first (second) eigenmode. As shown in Fig. 2, the structure of the first (second) eigenmode is even (odd) with respect to the rational surface.

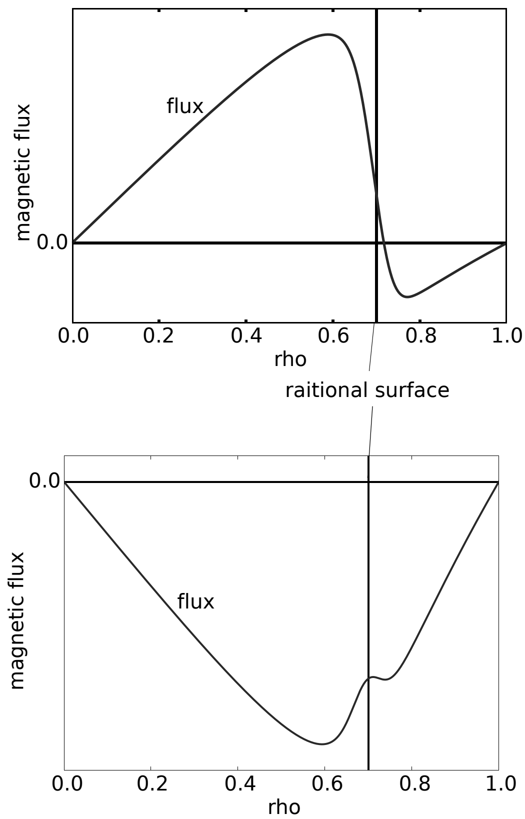


Fig. 2. Mode structure of the first (upper) and second (lower) modes.

In order to evaluate the magnetic island formation systematically, the characteristic index,

$$I_\xi \equiv \frac{\omega^2}{\xi_r a}$$

is introduced, where $\omega$ is the magnetic island width, $\xi_r$ the displacement to the minor radius direction and $a$ the minor radius, respectively. By used this index, it is found that the magnetic island due to the second eigenmode is larger than that due to the first eigenmode when the displacement is in the same range.

1) Watanabe, K. Y., et al.: Fusion Sci. Technol. **46** (2004) 24.
2) Xiao, F., et al.: Comput. Phys. Commun. **94** (1996) 103.
3) Huamo, W., Shuli, Y.: IMPACT Comput. Sci. Eng. **1** (1989) 217.
4) Ueda, R., et al.: Phys. Plasmas 21 (2014) 034405.