§4. Nonlinear Evolution of 3D MHD Instability in LHD

Miura, H., Nakajima, N., Hayashi, T.,[1] Okamoto, M.

We have beeing carrying out direct numerical simulations of fully three-dimensional, nonlinear MHD in the LHD. An initial condition with the $\beta_0 = 4\%$ and $R_{ax} = 3.6m$ has been provided by using the HINT code.[1)] The numbers of grid points are 97×97 on a poloidal section and 640 in the toroidal direction. The parallel and perpendicular heat conductivity $\kappa_{//}$ are typically set to 1×10^{-3} and 1×10^{-6}, respectively. The viscosity and resistivity are 2×10^{-3} and 1×10^{-6}, respectively. The outline of our numerical results is that the parallel kinetic energy is as strong as the perpendicular kinetic energy. The parallel flow is excited as a part of the linear eigen-function.

In order to study the kinetic energy evolution in the view of the linear analysis, the velocity vector $\boldsymbol{v}$ is decomposed into the paralle, normal and binormal components as

$$\boldsymbol{v} \quad = \quad v^{\boldsymbol{b}}\boldsymbol{e}_{\boldsymbol{b}} + v^{\nabla\psi}\boldsymbol{e}_{\nabla\psi} + v^{\nabla\psi\times\boldsymbol{b}}\boldsymbol{e}_{\nabla\psi\times\boldsymbol{b}}. \tag{1}$$

where $\boldsymbol{e}_i(i = \boldsymbol{b}, \nabla\psi, \nabla\psi \times \boldsymbol{b})$ are the unit vectors in the three directions. Then the Fourier-transform of the three components in the Boozer-coordinate system provides us the information about the time evolution of each Fourier modes of the three components. Typical observations on the Fourier modes are as follows.[2)]

In Fig.1(a), (b) and (c), time evolutions of the amplitudes of the Fourie modes $m/n = 1/1$ and $2/1$ of the normal, parallel and binormal components are shown, respectively, for the two values of $\kappa_{//}$. The Fourier amplitudes of these modes grows exponetially because of the linear (pressure-driven) instability. It is observed that the Fourier modes of the three components are smaller in the simulation with the larger parallel heat conductivity $\kappa_{//} = 1 \times 10^{-3}$ than in the simulation with the smaller one, $\kappa_{//} = 1 \times 10^{-6}$. A clear distinction among the three velocity components are found in their behaviors after the nonlinear saturations in the simulation of $\kappa_{//} = 1 \times 10^{-3}$. While the Fourier modes of the normal and binormal component of the velocity are scattered away by the nonlinear interactions after the nonlinear saturations, their amplitudes being small, the Fourier modes of the parallel components keeps its amplitude till the end of the simulation ($t = 1400\tau_A$, beyond the time range in Fig.). The plasyma appears to approach a near-equilibrium state keeping the parallel velocity relatively large, because the parallel velocity does not have direct relations with the interchange instability.

[1] Deceased April 2006

1) H. Harafuji, T. Hayashi and T. Sato, J. Comp. Phys., **81** (1989) 169.

2) H. Miura, N. Nakajima, T. Hayashi and M. Okamoto, to appear in Fusion Science and Technology.

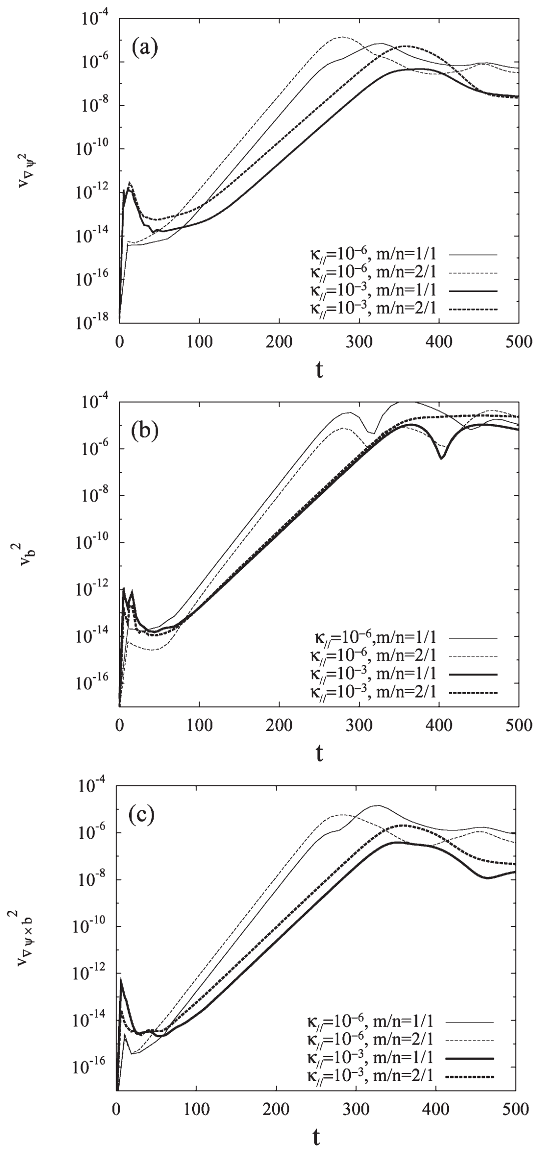

Fig. 1: Time evolutions of the amplitudes of the $m/n = 1/1$ and $2/1$ Fourier modes of (a)normal, (b)parallel and (c)binormal components of the velocity.