§10. MHD Direct Numerical Simulations of LHD with 3.6m Vacuum Magnetic Axis

Miura, H., Nakajima, N., Hayashi, T., Okamoto, M.

Growth and saturations of pressure-driven instabilities in LHD with 3.6m vacuum magnetic axis are investigated by means of direct numerical simulations (DNS) of compressible and nonlinear magneto-hydrodynamic (MHD) equations. The MHD equations are described in the helical-toroidal coordinate system, discretized by the central-finite-difference scheme and marched in the time direction by the Runge-Kutta-Gill scheme.1,2) Initial equilibrium is calculated by the use of the HINT code, having the central beta β_0=4%, the vacuum magnetic axis Rax=3.6m.3) Preliminary simulations under the half-pitch symmetry have shown that moderate poloidal(m) and toroidal(n) Fourier modes are dominated by the resistive ballooning instability.3)

DNS without half-pitch symmetry shows growth of the m/n=2/1 mode as the most dominant mode. In Fig.1, contours of the pressure fluctuations at three poloidal cross-sections and isosurfaces of the positive and negative pressure fluctuations in half-transparent colors are shown. Two sets of positive and negative fluctuations are observed both on the cross-sections and in isosurfaces. Prior to the growth of m/n=2/1, m/n=15/10 resistive ballooning mode is observed. However, in the course of the development of the m/n=2/1 structures, m/n=15/10 mode disappears. The detailed analysis should be proceeded by the spectral-decomposition, which is now undergoing.

In Fig.2, streamlines of the three-dimensional velocity are shown. Dark belts in the left and right hand side in the figure represents the isosurfaces of the pressure on vertically- and horizontally-elongated cross-sections, respectively. The initial points of the streamlines are provided on the vertically-elongated cross-section. The streamlines from spiral structures which are associated with swirling motions of m/n=2/1 modes. However, there is a clear difference between the spirals in upper- and lower-half plane of the cross-section. We find that the streamlines which start from the upper-half plane of the vertically-elongated cross-section stay near the vertically-elongated cross-sections. It represents that the toroidal component of the velocity vector is small and the fluid motion is nearly two-dimensional. However, on the other hand, the swirling motions which start from the lower-half plane are advected strongly toward right-hand-side of the figure. It represents that the toroidal component of the velocity vector is very strong and the fluid motions are fully three-dimensional. A simple analysis shows that about one-third of the mean kinetic energy is occupied by the toroidal fluid motions at the time of the saturation time of the energy growth. Furthermore,, it is often observed that the streamlines are convergent especially at the centre of the vortices. It represents that the flows are compressible and streamlines are not connected anywhere. These numerical results demonstrate that the three-dimensional fluid motions with toroidal flows and compressibility of the MHD fluid can be essential for understanding of the plasma behaviors in LHD.

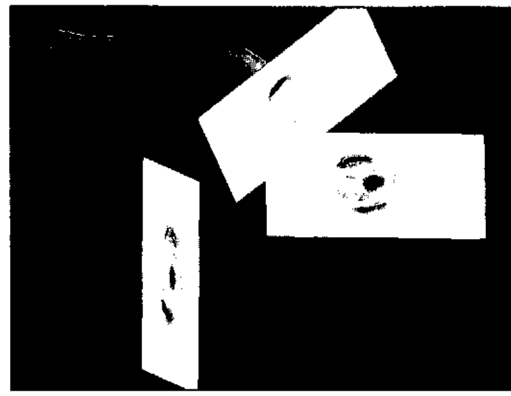

Fig. 1. Contours of the pressure fluctuations on poloidal cross-sections. Isosurfaces of positive and negative pressure fluctuations are also shown.

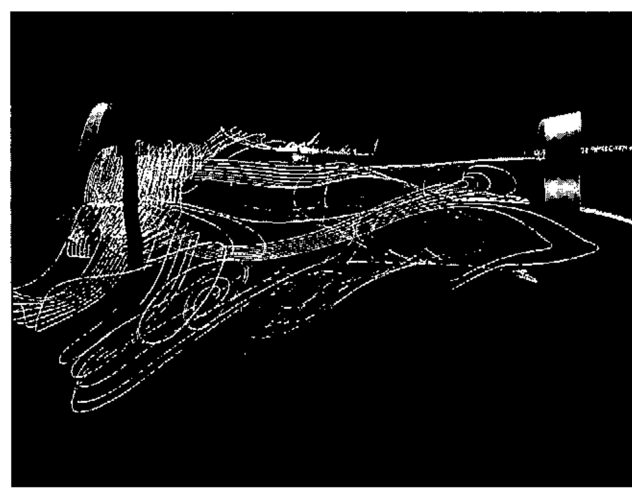

Fig. 2. Streamlines associated with m/n=2/1 vortical motions. It is clearly observed that streamlines are elongated into the toroidal direction. It shows dominance of toroidal component of the fluid velocity vector over the poloidal component. It is also observed that spiral streamlines are convergent at their centers, which means that the fluid motions are compressible.

Reference

1) Miura, H. et al., Phys. Plasmas **8** (2001) 4870

2) Hayashi, T. et al., Proc. 19th IAEA Fusion Energy Conference (Lyon, France, 14-19 October 2002) IAEA-CN-94/TH/6-3)

3) Miura, H. et al., J. Plasma Fusion and Res. SERIES **5** (2002) 495.