§ 1. Excitation of a m/n = 2/1 Mode in 3D Nonlinear MHD Simulation in LHD

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We have conducted direct numerical simulations of fully three-dimensional, nonlinear MHD in the LHD. A pressure-driven instability with m/n=2/1 Fourier mode is excited. It brings about a mushroom-like deformation of the plasma pressure and leads to a transition to a nearly-equilibrated state.

An initial condition with the $\beta_0 = 4\%$ and $R_{ax} = 3.6m$ has been provided by using the HINT code.[1] The number of grid points are 97×97 on a poloidal section and 640 in the toroidal direction. The heat conductivity and viscosity are set to 1×10^{-6} and 2×10^{-3}, respectively. Two values 1×10^{-6} and 5.16×10^{-6} are used as the resistivity η. These dissipative coefficients are isotropic and constant throughout simulations. The numerical code has been developed by the authors.[2)–4)]

In Fig.1, time evolutions of the kinetic energy are shown for the two values of the resistivity. The time evolutions obtained by simulations under the half-pitch stellarator symmetry are also shown for reference. Thick lines represent data of full-torus simulations and thin lines represent half-pitch simulations. Solid and dashed lines are of $\eta = 5.16 \times 10^{-6}$ and 1×10^{-6}, respectively. The kinetic energy increase because of the pressure-driven instability. Based on an observations of fluctuating quantities such as the pressure fluctuations and poloidal currents, the instability is considered to be a sort of ballooning instability. We find that saturation levels of the growth in full-torus simulations are much higher than the half-pitch system.

In Figs.2, pressure contours are shown with streamlines on (a)horizontally- and (b)vertically-elongated poloidal sections. The streamlines are drawn only with the velocity components (that is, without the velocity component in the toroidal direction) on the poloidal sections and represent topology of velocity vectors on the planes. We find that the m/n=2/1 mode dominates the field. The m/n=2/1 modes in the velocity field forms two pairs of anti-parallel vortex pairs. The vortices advect each other toward outside of the poloidal sections. The pressure is advected by the vortex pairs and forms a pair of mushroom-like structures on the plane. The deformation brings about re-distributions of the pressure and work to stabilize the plasma motions.

In the end of our simulations, the system approaches to a nearly-equilibrated state. It indicates that the pressure-driven instability is not destructive. It may explain an experimental fact that LHD plasma stays relatively stable even with an inner-shifted vacuum magnetic axis $R_{ax} = 3.6m$ or $3.5m$, which are unstable withing a framework of an ideal MHD stability.

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

2) H. Miura, T. Hayashi and T. Sato, J. Plasma and Fusion Research SER.**4**, 476 (2001)

3) H. Miura, T. Hayashi and T. Sato, Phys. Plasmas **8**, 4870 (2001)

4) H. Miura, T. Hayashi and T. Sato, J. Plasma and Fusion Research SER.**5**, 495 (2003)

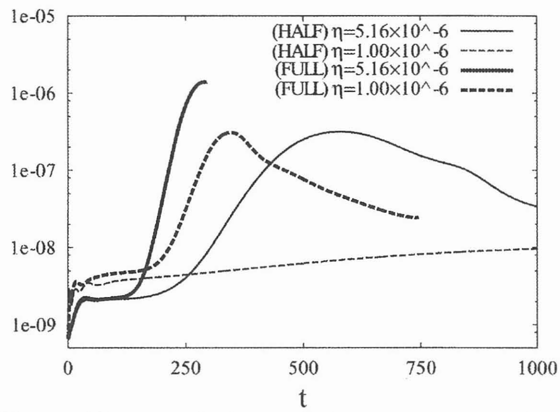

Fig.1: Time evolutions of the kinetic energies in full-torus and half-pitch simulations.

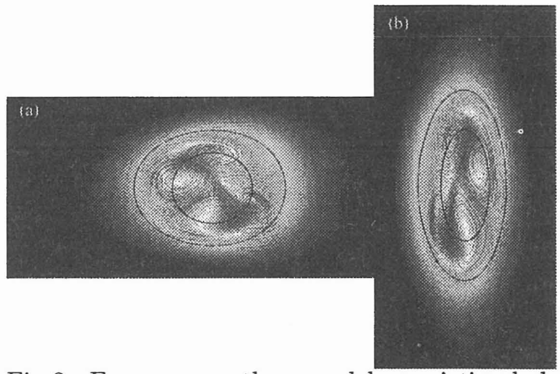

Fig.2: Energy growth caused by resistive ballooning modes. Solid and dashed lines are for runs of series A and B, respectively.