§28. A Sub-gird-scale Effect in Hall MHD Simulation in the Large Helical Device

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A sub-grid-scale effect in Hall MHD simulation in the Lage Helical Device is studied by means of full three-dimensional (3D) nonlinear simulations of pressure-driven instabilities in LHD.

Plasma motions which start from unstable equilibrium is typically studied by means of stability analysis and numerical simulations of magneto-hydrodynamics (MHD) equations. An increase of a numerical resolution in MHD simulations brings about overlaps of the minimum scale in the simulations and the scales discarded in the MHD approximations. In order to predict or study various phenomena by means of numerical simulations with physical reliability, it is preferable to extend MHD equations so that the scales shorter than the MHD approximation, such as the ion skin depth, are taken into account. Candidates of extensions of MHD equations are given by Hazeltine and Meiss[1)], Sugiyama and Park[2)] ,and Shnack et al.[3)] However, recent trends in fusion studies suggests that we can be requested to carry out numerical simulations so that we can feedback the knowledge acquired by the simulations to experiments or analysis of experimental results as quickly as possible. Unfortunately, both the increasing numerical resolution and the increasing complexity of the equations bring about a very long computational time and a huge computational memory requirement, making a sharp contradiction with the requirement of a short-time computation.

In order to solve the contradiction, we try to construct a numerical model for short length scales so that the short-scale-effects are taken into account of our simulations through the numerical models, not through a direct computation of the effects on fine numerical grids. In order to enable this approach, which is often called as the large eddy simulation, to an extended MHD model, we have to construct some sub-grid-scale models for nonlinear terms. As the first step, we adopted the Hall MHD model as the target, and studied the influences of sub-grid-scale effects in Hall MHD simulations in the Large Helical Device.

We have compared two simulations with different numerical resolutions, the higher resolution (number of grid points $193 \times 193 \times 640$) and the lower resolution ($97 \times 97 \times 640$) by the use of the MINOS code4). The simulation of the lower resolution does not resolve the ion skin depth sufficiently. In other words, the lower resolution simulation is a sort of the large eddy simulation without any sub-grid-scale models. In Fig.1, the time evolution of (a) the m/n=2/1 and (b) the m/n=4/2 Fourier coefficients the velocity are shown, where m and n are the poloidal and the toroidal wave numbers, respectively. The three velocity components (normal, parallel and binormal) are plotted for the high resolution run (thick lines) and for the low resolution run(thin lines). The abscissa is the time normalized into the toroidal Alfven unit time. We find in Fig.1 that the growth of the m/n=2/1 and 4/2 coefficients are underestimated in the low-resolution simulation. The result suggests that the sub-grid-scale models should be constructed so that the models compensate the underestimated energy somehow. In other words, the model should contain the backward energy transfer in the wave number space.

These numerical results will be taken into account in our future numerical simulations. These numerical results have been presented in the IAEA Fusion Energy Conference at Daejeon, Korea, 2010.[5)]

1) Hazeltine, R.D., and Meiss, J.D.: *Plasma Confinement* (Addison-Wesley Pub., 2003)
2) Shnack, D.D.. et al.: Phys. Plasmas **13** (2006) 058103.
3) Sugiyama, L.E. and Park, W..: Phys. Plasmas. **7** (2000) 4644.
4) Miura, H.: Fusion Sci. & Technology **51** (2007) .8.
5) Miura, H. and Nakajima, N.: IAEA 23rd FEC (Oct. 11-16 2010, Daejeon, Korea) TH/P9-16.

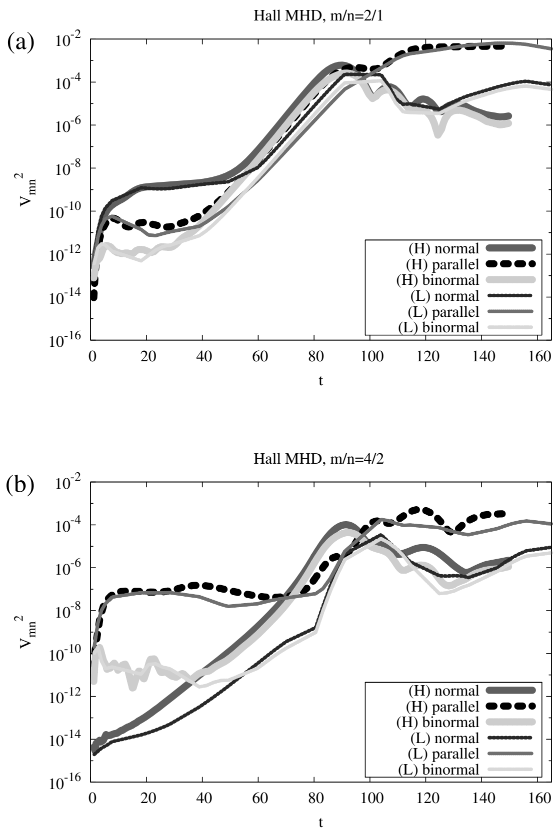

Fig.1: the time evolution of (a) the m/n=2/1 and (b) the m/n=4/2 Fourier coefficients the velocity are shown, where m and n are the poloidal and the toroidal wave numbers, respectively.