§1. Influences of Short-wave Truncation in MHD/Hall-MHD Simulations

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We have been studying the influences of moderate or high wavenumber ballooning modes on plasma dynamics under an unstable magnetic configuration. While unstable modes of the interchange/ballooning instability can be stabilized when they consist of relatively low wavenumber Fourier coefficients, their behaviors can be dangerous once moderate or high wavenumber unstable modes grow[1]. Since the interchange and the ballooning instability have a nature such that the growth rates of the unstable modes become larger as the toroidal/poloidal mode numbers become larger, the influences of the growth of the moderate or high wave number modes can be relevant to understanding physics of plasma dynamics.

Many subjects of instability are often studies by means of the numerical simulations of the magnetohydrodynamic (MHD) equations. However, because of the short-wavenumber properties of the instability in the above, the MHD approximation can be valid for moderate or high wavenumber unstable modes. In fact, wavelengths of typical unstable modes are shorter than the ion skin depth, influences of which are neglected in the single fluid MHD equations. Thus, on one hand, we should move on to simulations of extended- or two-fluid equations in which influences of smaller scales are taken into account. However, on the other hand, the two-fluid simulations can be often expensive not only because of turbulent motions but also of very fast waves such as whistler waves, frequency of which is a quadratic function of the wavenumber.

In order to carry out simulations of two-fluid equations with relatively small computational cost, we plan to model the two-fluid equations by an approach similar to the Large Eddy Simulations (LES) of fluid mechanics. As the preliminary study of the approach, we have carried out direct numerical simulations of the Hall MHD turbulence and compare the numerical results to the MHD turbulence simulation. In the comparative study we aim to figure out influences of the short-wave filtering to the Hall MHD dynamics. [2] For the sake of clarifying the filtering effects, we have also carried out the simulations in which all the physical variables are filtered by the low-pass filter, the cut- off wavenumber of which is set slightly larger than the wavenumber of the ion skin depth. In Fig.2, the time evolutions of the magnetic energies in the DNSs and the filtered simulations of the MHD/Hall MHD turbulence are shown. It is easily found in Fig.2 that the magnetic energy in the filtered simulation of MHD turbulence (dotted-dashed thick lines) decays almost monotonically even though the quantity in the DNS of MHD turbulence (thin solid line) shows a small peak at t=0.25. It suggests that some important properties of MHD turbulence are modified by the low-pass filtering. On the other hand, the other two lines in Fig.2 show qualitatively similar behaviors. It suggests that the low-pass filtering does not modify the basic property of the Hall MHD turbulence. Our current understanding is that the introduction of the Hall term modifies the inter-scale energy transfer as well as the energy exchange between the kinetic and magnetic energies. Consequently, the magnetic energy in the Hall MHD turbulence can be less sensitive to the low-pass filtering (that is, the truncation of short wavenumber coefficients). Such a nature of the Hall MHD turbulence will be studied further in order to construct a sub-ggrid scale model for LES of the Hall MHD system.

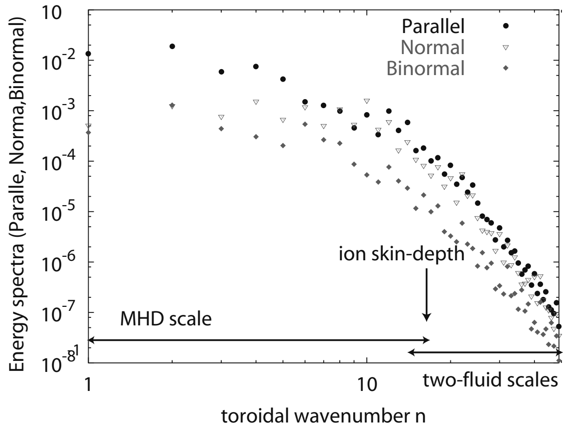

Fig.1. Energy spectra of the there velocity components (parallel, normal, and binormal to the magnetic field lines) are shown as the function of the toroidal wave number.

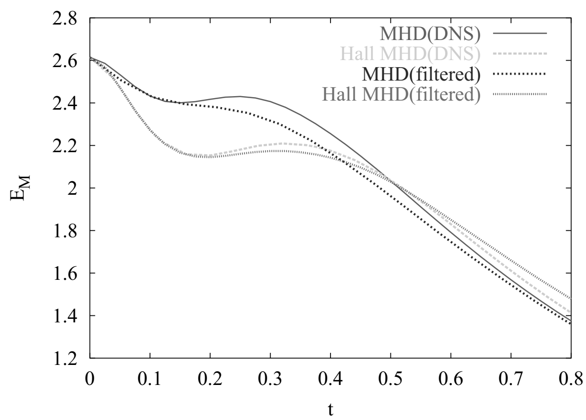

Fig. 2. Time evolutions of the magnetic energy in the DNSs of MHD turbulence (thin solid line) and Hall MHD turbulence (thick solid line), filtered simulations of MHD turbulence (dotted-dashed line) and Hall MHD turbulence (solid line) are shown.

1) H. Miura and N. Nakajima, Nuclear Fusion **50** (2010) 054006.

2) H. Miura: to appear in Plasma Fusion Research **6** (2010)