Truncation of scales shorter than the ion skin depth in homogeneous Halll-MHD turbulence

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Studies of magnetohydrodynamics (MHD) simulations provide basic insights to many plasma phenomena such as instabilities in torus fusion devices. For example, full-3D simulations in the Large Helical Device depict detailed views of nonlinear evolutions of ballooning modes[1]. However, the applicability of the single-fluid MHD equations is intrinsically restricted to relatively large-scale motions and recent numerical studies of hot plasmas often cover a wide range of space and time scales of turbulence. Plasma turbulence in fusion is out of the single-fluid MHD description, and it is typically studied by the use of either extended MHD, the two-fluid, or gyrokinetic equations.

The Hall-MHD equations are one of the simplest fluid models in which two-fluid effects are partially taken into account. The difference of the Hall MHD equations from the single-fluid MHD equations is seen only in the Hall term of the induction equation. However, the difference brings about significant modifications of the MHD dynamics. For example in Rayleigh-Talyor-type instability, the introduction of the Hall term means disappearance of unstable modes over some wavenumbers[2]. The introduction of the Hall term also brings about the Whistler-Alfven waves[3], which limit the time step width severely in simulations. For the purpose of avoiding the time step width limitation, a hyper viscosity or a sort of numerical smoothing is often adopted in simulations. However, such an artificial truncation of small scales often causes unphysical behaviors numerical results, especially in turbulence simulations.

In this presentation, in order to estimate influences of small-scale truncations by an artificial diffusivity/smoothing in plasma turbulence simulation, we carry out simulations of homogeneous Hall MHD turbulence with a truncated Hall MHD model. The numerical results are compared to those of direct numerical simulations of Hall MHD turbulence. We also try to estimate compensating the truncated Fourier modes by the use of the eddy viscosity and the eddy resistivity.

[1]H.Miura and N.Nakajima, 22th IAEA Fusion Energy Conference, Geneva, Switzerland, 13-18 October 2008, TH/P9-16
[2] J.D.Huba and D. Winske, Phys. Plasmas 6 (1998) 2305.
[3] S.Ohsaki and S.Mahajan, Phys. Plasmas 11(2004) 898.