§29. Compensation of Energy Transfers by Quadratic Terms in Fully Developed Hall MHD Turbulence

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Hall MHD system has four quadratic interaction terms, i.e. advection of fluid plasma, Lorentz force, magnetic induction and the Hall term, and is expected to have a wide variety of nonlinear phenomena. The analysis of the contributions of each quadratic mode interaction to the energy transfer process is important to develop appropriate simulation model of fusion and space plasmas such as LES [1].

We analyzed the snapshot datas of a direct numerical simulation (DNS) of fully developed homegeneous, isotropic freely decaying turbulence. We performed DNS on a periodic box with 512^3 grid points. The magnetic Reynolds number of the obtained data is about 80 and rather stationary for $t \geq 1$. Since the datas are obtained by the freely decaying simulation, the obtained transfer function are expected to reflect the characteristics which is intrinsic to the HMHD system.

In order to compare the intensity of the quadratic mode interactions in a freely decaying turbulence for different time snapshots, the velocity and magnetic fields are band pass filtered according to the Kolmogorov scale, which is the fundamental scale unit of dissipation range, and their amplitudes are normalized by using the energy dissipation rate[2]. In Fig.1 the noramalized kinetic and magnetic energy spectra are shown. Each of their functional form are well collapsed. This implies that the solution is in a self-similar state and some universal turbulent features are expected.

In Fig.2 the normalized energy transfer functions for each quadratic term and for snapshots at $t = 1.0$, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, and 5.0 are shown. According to these two normalization technique, the amplitude and functional form of energy transfer functions become comparable (see Fig.2).

It is interesting that, though the amplitude of the energy spectra agrees well each other after the normalization, the energy transfer due to the nonlinear terms, i.e. advection effect and the Hall term effect, are gradually decreasing. This implies that the contribution of these terms relative to the other terms reduces in time. This may suggest that some topological features of the velocity and magnetic fields slowly changed after their energy spectra obtain equilibrium form since amplitude and scale factors are normalized.

Furthermore, it is remarkable that the net energy transfer functions, given by the sum of advection and the Lorentz force term for the kinetic energy and that of magnetic induction and the Hall term for the magnetic one, respectively tend to converge to a stationary functional form (see Fig.2). This implies that the reductions of energy transfer by fluid advection and the Hall term effect are respectively compensated by those due to Lorentz force effect and magnetic induction. Analysis of this compensation is now underway.

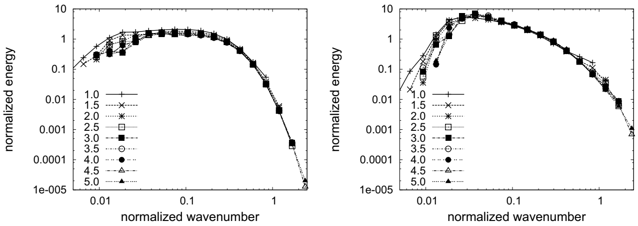

Fig. 1: Normalized energy spectra: left: kinetic energy, right: magnetic energy.

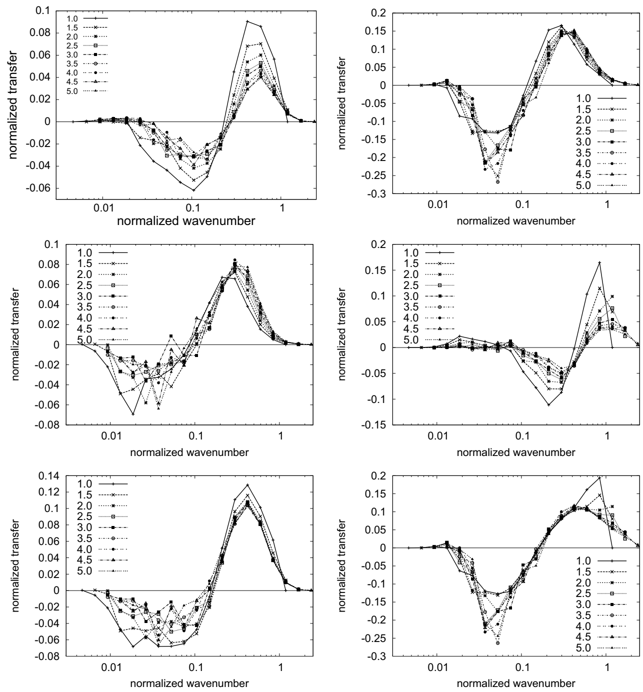

Fig. 2: Normalized energy transfer functions of each terms in HMHD turbulence; left top: advection, right top: magnetic induction, left middle: the Lorentz force, right middle: the Hall term effect, left bottom: sum of advection and Lorentz force, right bottom: sum of magnetic indection and the Hall term effect.

1) Miura, H., Araki, K.: *Plasma Phys. Control. Fusion*, **55**: 014012, 2013.

2) Araki, K., Miura, H.: submitted to *Plasma Fusion Res.* (as a proceeding of ITC22).