§22. Development of Multi-Hierarchy Simulation Model for the Full Understanding of Magnetic Reconnection

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It is believed that magnetic reconnection plays an important role, for instance in solar flare, geomagnetic substorm, and tokamak disruptions. Furthermore, magnetic reconnection is a typical multi-hierarchy phenomenon. The global change in magnetic field topology occurs, while kinetic process controlled by microscopic physics is necessary in the vicinity of reconnection point as the trigger. Therefore, for the full understanding of magnetic reconnection as a multi-hierarchy phenomenon, we develop a (three-dimensional) multi-hierarchy simulation model which can deal with both microscopic and macroscopic physics consistently and simultaneously [1].

The multi-hierarchy structure of magnetic reconnection has a special feature that space-time scale is changed by the distance from the neutral sheet (reconnection points). By using this feature, we employ the domain decomposition method for our multi-hierarchy simulation model: the domains differ in algorism. Dynamics in the domain near the neutral sheet are controlled by kinetic physics, and then are solved by particle (PIC) simulation [2]. Let us call this domain PIC domain. On the other hand, plasma behaviors far away from the neutral sheet (reconnection points) can be expressed as one-fluid, and thus are described by MHD simulation. This domain is named the MHD domain. In order to interlock PIC and MHD domains smoothly, the Interface domain which has a finite width is inserted between PIC and MHD domains. The physics in the Interface domain is calculated by both PIC and MHD simulations. Let us note that both two models are needed to be approximately satisfied in the Interface domain.

We examine applicability of our multi-hierarchy model. In 2007FY, multi-hierarchy simulations of Alfvén wave propagation are reported [3]. Now we perform multi-hierarchy simulation of plasma injection from MHD to PIC domains. Figure 1 shows schematic diagram of simulation box. PIC domain is located at the center of the box. MHD domains are at both sides of PIC domain. There exist the Interface domains between MHD and PIC domains. The system is periodic in x and z directions and is free in the y direction. The uniform external magnetic field is taken to be x direction. The z-component of electric field is imposed at the left and right boundaries. According to ExB drift, plasma is injected inward in the y direction.

Figure 2 demonstrates spatial profiles of mass density ρ at the various times. Here ρ_0 is the initial mass density. We can see that plasma smoothly flows from MHD to PIC domains through the Interface domain, and mass density in PIC domain increases.

Now, as a first step of magnetic reconnection multi-hierarchy simulations, we improve the model shown in Fig. 1 to one with upstream of PIC domain connected to MHD domain in reconnection configuration.

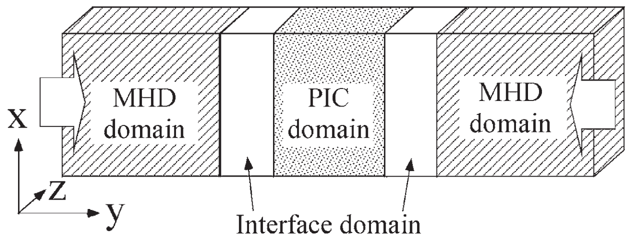

Fig. 1: Simulation box for numerical test of the multi-hierarchy model. The uniform external magnetic field is taken to be x direction.

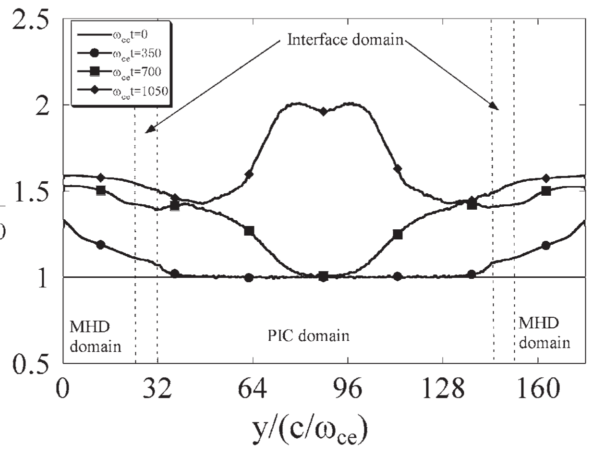

Fig. 2: Spatial profiles of mass density ρ at the various times.

1) R. Horiuchi, H. Ohtani, and A. Ishizawa, J. Plasma Phys. **72** (2006) 953.

2) H. Ohtani and R.Horiuchi, Plasma and Fusion Research **4** (2009) 024.

3) S. Usami, H. Ohtani, R. Horiuchi, and M. Den, Communications in Computational Physics **4** (2008) 537.