Large-scale electromagnetic particle simulations of magnetic reconnection

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It is widely believed that magnetic reconnection plays an important role in the magnetospheric substorm and the solar flare. However, physical processes around the diffusion region are not well understood. Electromagnetic full particle simulations, in which both electrons and ions are treated as particles, are very effective to understand physics around the diffusion region, because the kinetic processes of electrons and ions are important there. The diffusion region consists of the electron diffusion region, where the electron dynamics are dominant, and the ion diffusion region, where the ion dynamics is important. The electron diffusion region has been studied extensively by the use of the full particle codes, and well understood on its structure. Ion-scale description of magnetic reconnection is, however, not well understood, because it is difficult to conduct a particle simulation whose box size is large enough to describe an ion-scale structure of the diffusion region due to the limitation of computer resources. In the most particle simulations, magnetic reconnection is interrupted before it evolves into the ion scale because of the compression of magnetic flux and plasma in the large magnetic island. In order to overcome such a problem, we have developed a new electromagnetic full particle code using adaptive mesh refinement (AMR) technique, and are successful to realize effectively high-resolution simulations.

This time we conduct two-dimensional electromagnetic particle simulations of magnetic reconnection by the use of our new code. We examine two runs with different sizes of the simulation box; the size is approximately the same as those in the conventional particle codes for the first run (Run1), and ten times larger for the second run (Run2). The initial evolutions of magnetic reconnection as described below are basically identical in the two runs.

1.The magnetic islands are formed in association with the tearing instability.

2.The inductive electric field (Ey) evolves rapidly and the electron diffusion region is formed.

3.Ey is saturated and became static.

4.The intensity of Ey starts to drop.

We find that the physical reasons to cause the process 4 are different between the two runs. In Run1, the process 4 is caused by the compressive effect in the magnetic island as mentioned above. On the other hand, in Run2, such an effect is not dominant due to the large system size, so that some other mechanisms are responsible for it. It is interesting that the ion diffusion region starts to be formed in association with the process 4. The electron flow directing into the electron diffusion region is changed in the ion diffusion region. The strong electron flow is basically along the magnetic field line before it enters the ion diffusion region, but the inward electric field is strong in the ion diffusion region so that the field-aligned motions of electrons are interrupted and ExB drift motions are dominant. In other word, the ion dynamics changes the electron flow in the ion diffusion region. Thus the ion dynamics may contribute the process 4 in Run2 by controlling the electron flow.

In this paper, we will explain the difference in the causes for the process 4 between Run1 and Run2, and discuss the role of the ion dynamics.