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Role of magnetic islands in energy conversion process of collisionless driven reconnection

無衝突駆動リコネクションのエネルギー変換過程における磁気島の役割

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The influence of a guide field and roles of magnetic islands on collisionless driven reconnection are investigated by means of electromagnetic particle simulation in an open system. In the presence of the guide field, energy conversion to both ions and electrons is suppressed to a lower level because the dissipation region shrinks as the guide field is amplified. There are two states in time evolution of collisionless driven reconnection, i.e., no-island state and multi-islands state. The energy conversion is enhanced due to the existence of magnetic islands because a relatively larger reconnection rate is realized at the multi-islands state.

1. Introduction

It is widely believed that magnetic reconnection observed in various natural systems is controlled by common or similar physical processes, regardless of large differences in magnetic configurations and spatial-temporal scales. However, because unmagnetized region shrinks with a guide field, it is expected that magnetic reconnection in a system with a strong guide field, such as fusion devices, may be altered from that in natural systems with no or a small guide field, such as solar corona and the earth's magnetosphere. Furthermore, magnetic islands are sometimes observed to grow in a current sheet and modifies reconnection physics. Based on results from two-dimensional PIC simulations for an open system with an external driving source, the influence of a guide field and roles of magnetic islands on collisionless driven reconnection are investigated.

2. Model

We utilized particle simulation model, “PASMO”, which has been developed for particle simulation studies of collisionless driven reconnection in an open system [1, 2]. An external driving electric field is imposed to supply the particles into the simulation domain from the upstream boundary. As an initial condition we adopt one-dimensional equilibrium with a uniform guide field and constant temperature [3]. By controlling an external driving field, we find that two different kinds of states are realized in the time evolution of a reconnection system starting from the same initial condition, i.e., the first is a state with no magnetic islands in the current sheet, and the second is a state at which magnetic islands are frequently generated and grow in it. We carried out four simulation runs with different guide field and a control parameter of an external driving field, i.e., expansion speed of plasma inflow (see Table I).

Table I. Simulation parameters and results

	No Guide field (B_{z0}=0.0)	Strong guide field (B_{z0}=2.0)
Slow expansion ($V_{ex} = V_{A0}$)	No island	No island
Fast expansion ($V_{ex} = 2V_{A0}$)	Multi islands	Multi islands

3. Influence of a guide field

Based on the simulation results for a strong guide field, we examined the ion and electron force balance in the out-of-plane direction [3]. The off-diagonal pressure tensor term becomes dominant within a particle meandering scale and sustains the reconnection electric field for both electrons and ions. In other words, the particle kinetic effect due to the meandering motion plays a key role in breaking the plasma frozen-in condition even when a strong guide field exists.

We examined the energy conversion process in the presence of a strong guide field and compared its rate with that for no guide field case. Figure 1 shows the temporal evolution of the energy conversion rate from the EM field to plasmas for different guide fields. The conversion rate decreases as a guide field is intensified. This result suggests that, in the presence of the guide field, energy conversion process to both ions and electrons is suppressed to a lower level because the dissipation region shrinks as the guide field is amplified. On the other hand, the rate to ions is always twice or thrice of that to electrons, regardless of whether a guide magnetic field exist.

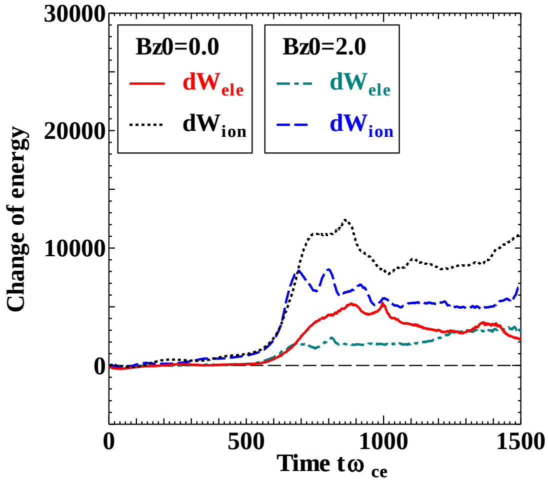

Fig.1. Energy conversion rate to ion and electron for two different guide fields.

4. Roles of magnetic islands

The relationship between energy conversion rate and an existence of magnetic islands is examined based on the simulation results for the cases with the strong guide field and different expansion speeds, as shown in Table I. Figure 2 shows the temporal evolution of the energy conversion rate from the EM field to plasmas for different expansion speeds, where "no-island" and "multi-islands" correspond to the cases for slow expansion speed and for fast expansion case, respectively. It is clear in Fig. 2 that the energy conversion is enhanced due to the existence of magnetic islands, while the EM energy is dominantly converted to ion energy regardless of the existence of magnetic islands.

The detail analysis reveals that there are two states in time evolution of collisionless driven reconnection. That is, no-island state with a relatively small reconnection rate is realized in a slow expansion case, while multi-islands state with a large reconnection rate is realized in a fast expansion case.

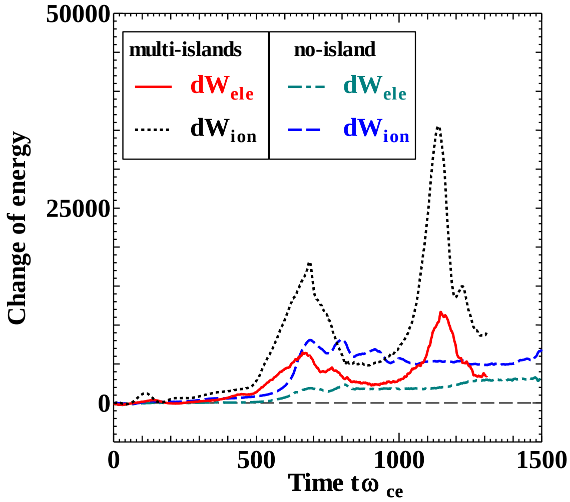

Fig.1. Energy conversion rate to ions and electrons for two different expansion speeds.

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