§6. The Effect of MHD Turbulence on Magnetic Reconnection

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Fast magnetic reconnection in high Lundquist number plasmas is a key process for understanding explosive phenomena in space plasmas such as solar flares. However, conventional steady-state theoretical studies for resistive magnetohydrodynamics (MHD) could not explain the strong enhancement of the reconnection rate.[1), 2)] On the other hand, in recent simulation studies, it was indicated that non-MHD / kinetic effects such as the Hall effect can significantly enhance the reconnection rate.[3)] Thus, fast magnetic reconnection can naturally be realized in a kinetic-scale current sheet, where the magnetic energy is rapidly liberated. However, how will the kinetic-scale current sheet be formed? In realistic very high Lundquist number plasmas, there is an extremely large gap between scales of the magnetic energy input and dissipation. It is expected in this situation that an MHD turbulence is developed during current sheet thinning and may affect the fast reconnection processes. Therefore, we intend to clarify roles of the MHD turbulence in magnetic reconnection. Particularly, in this study, we perform a two-dimensional very-high-resolution MHD simulation of the resistive tearing instability and examine basic properties of high Lundquist number reconnection.

As a numerical method, we adopt the finite-volume method in which control volume averages of the conservative variables are updated using the differences of the numerical fluxes at the interfaces of the control volume. The numerical fluxes are computed by the Harte-Lax-van Leer-Discontinuities (HLLD) approximate Riemann solver for MHD.[4)] The induction equation is solved by a newly developed HLL-type flux-CT method in order to suppress numerical divergence of the magnetic field and perform a very-high-resolution simulation for a long time.[5)] In order to obtain higher-order accuracy, Monotone Upstream-centered Scheme for Conservation Laws (MUSCL) is applied. In particular, we propose a set of approximate characteristics variables and interpolate it with a limiter function. These state-of-the-art numerical techniques enable us to investigate magnetic reconnection in compressible MHD turbulence.

We devote our attention to the two-dimensional resistive tearing instability in this study. A one-dimensional Harris current sheet is given as an equilibrium configuration for simplicity. The Lundquist number is set to be 1.57×10^5 in the present simulation. Initially, we impose a single-mode perturbation.

Fig. 1 shows the time development of the simulation. At the initial stage, the resistive tearing instability grows linearly. Subsequently, it seems to enter the Rutherford regime. After these regimes, Sweet-Parker-like current sheet which is thinned over time is formed. When the aspect ratio of the current sheet exceeds more than 100, the current sheet is destabilized for a secondary tearing mode.[6)] Although once the initial current sheet is stabilized for the secondary instability because the current sheet is broken by the plasmoid, newly produced current sheets are destabilized again in order to be thinned and be elongated by the plasmoid ejection. Then, multiple plasmoids are intermittently created and ejected. In the present parameter, about 6 to 8 plasmoids appear simultaneously. At the same time, the reconnection rate intermittently increases. In particular, some plasmoids selectively grow up very largely in a short time. These very large plasmoids sometimes move reversely due to strong reconnection at a strong current which is generated by own motion. The rapid increase of the reconnection rate seems to be correlated with the bounce motion of the very large plasmoids.

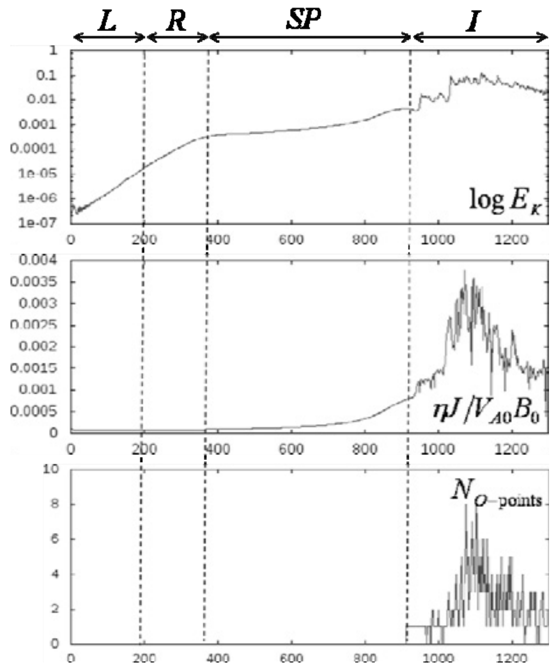

Fig. 1. From up to bottom: the time development of the kinetic energy, the reconnection rate at the minimum of the flux function, the number of plasmoids.

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3) Birn, J., et al.: Journal of Geophysical Research **106** (2001) 3715.
4) Miyoshi, T., Kusano K.: Journal of Computational Physics, **208** (2005) 315.
5) Miyoshi, T., Kusano K.: Plasma Fusion Research, **6** (2011) 2401124.
6) Loureiro, N. F., et al.: Physical Review Letters **95** (2005) 235003.