Two Fluid Effects on Reconnection during Counter-helicity Merging Experiment

Michiaki Inomoto[1]; Masaaki Yamada[2]; Hantao Ji[2]; Stefan Gerhardt[2]; Yang Ren[2]; Elena Belova[2]

[1] CAMT, Grad Sch of Eng, Osaka Univ; [2] PPPL

Collisionless magnetic reconnection is a key phenomenon on rapid dissipation of magnetic energy observed in space and laboratory plasmas, and has been investigated with astronomic observations, computer simulations and laboratory experiments. Recent satellite observations and hybrid/Hall-MHD simulation results suggests that the fast reconnection in collisionless regime is governed by the two fluid effects caused by the decoupled motions of the ion and the electron at the ion inertial scale near the X point [1-4].

A series of experiment studying collisionless magnetic reconnection has been carried out in the Magnetic Reconnection Experiment (MRX) device [5] in Princeton Plasma Physics Laboratory (PPPL). In MRX, two spheromak plasmas are produced simultaneously by a pair of flux core coils and merge into one through magnetic reconnection. Spontaneous formation of the quadrupole out-of-plane magnetic structure was recently observed in null-helicity merging experiment [6] in MRX. This result is a strong evidence that the Hall effect plays an important role in collisionless magnetic reconnection. The null-helicity merging has no guide (toroidal) field, therefore nearly ideal condition of two-dimensional reconnection of poloidal magnetic field is achieved and the observed quadrupole structure shows good agreement with simulation results.

There is another method to realize magnetic reconnection without guide field in MRX device: the counter-helicity merging of two spheromak plasmas. In this method, two spheromak plasmas with opposite toroidal field merge through reconnection of both poloidal and toroidal magnetic field. From the viewpoint of local magnetic configuration, this counter-helicity merging can be described that the parallel plasma current j// flows on the initial anti-parallel magnetic field lines B//. Since the out-of-plane magnetic field Bperp; created by the parallel plasma current j// is also anti-parallel at the X point, the counter-helicity merging provides magnetic reconnection without guide field, although the driven electric field is not perpendicular to the initial anti-parallel magnetic field lines B//.

There are two different counter-helicity cases: the two initial spheromaks have toroidal field polarities of ‘positive-negative’ and ‘negative-positive’ (toroidal field sign chosen with reference to the toroidal plasma current, which is in the same direction for both spheromaks). These two configurations show different features in magnetic probes, Langmuir probes and spectroscopic measurements. In one case, we observe X point structure which is radially pushed in from the axis position of the spheromaks with significant radially outward ion flow, while in the other case, X point structure was radially pushed out with almost no radially outward ion flow. A simple Hall-MHD model illustrates that this X point motion corresponds to the quadrupole out-of-plane magnetic field caused by the Hall effect since the reconnection plane in counter-helicity merging is tilted to the r-z observation plane. These observations are qualitatively consistent with the Hall-MHD computer simulation results. This work is supported by the US Department of Energy, the NSF, NASA and Japan Society for the Promotion of Science.

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