§5. Energy Conversion Mechanism of Magnetic Reconnection under High Guide Field

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The high-power reconnection heating has been studied in TS-3, TS-4 and MAST merging ST experiments as a promising solenoid (CS)-free startup with significant heating. Two ST plasmas axially merge together, forming a current sheet around the X-point. An important question is how the magnetic reconnection converts magnetic energy of two ST plasmas into thermal / kinetic energy of the produced ST and whether the high toroidal field decreases the conversion rate or not. Our 2D PIC simulation1) (with 2×10^9 particles in a domain of $x\times y$ = 512×256 λ_{DE}, where λ_{DE} is Debye length) and the TS-3/ TS-4 tokamak merging experiments reveal fast energy conversion from magnetic to ion kinetic / thermal energies in downstream regions. Here, we define q as B_{Z0} (out-of-plane magnetic field) over B_{p0} (in-plane magnetic field) and q=4 in our simulation.

The top panel of Fig. 1 shows 2D color map of ion temperature (kinetic energy) in one side of the downstreams for three different values of *q* in the PIC simulation [1]. The black lines in the three figures represent the same poloidal flux lines, indicating the reconnections with three different *q* are almost in the same stage. It is noted that the peak location of the ion total energy stays constant and the peak value slightly increases with *q*. However the flow energy component is dominant in $W_{i,tot}$ under high *q* condition, the flow energy of ions are suddenly damped by the reconnected field line and dissipated into thermal energy via fast shock or viscosity in the merging experiment.

The lower panel of Fig. 1 shows peak ion temperatures before (close circle) and after the merging with weak (open black circle) and strong (open red circle) compression force by inflow driving coils in TS-3 as a function of *q* [1]. However the ion temperature T_i after the reconnection is observed to increase inversely with *q* (from close to open black circle in the lower panel of Fig. 1), strong inflow driving compresses current sheet width shorter than the ion gyroradius together with density accumulation, triggering fast reconnection by two fluid/ kinetic effects and ejecting accumulated plasma. The ejected plasma suddenly damped by the reconnected field lines causes significant heating (red open circle in the lower panel of Fig. 1) via the fast shock or ion viscosity, indicating that the intermittent reconnection also plays an important role for the ion heating. The series of numerical and experimental results agree well with the recent MAST experiment under collisionless and high toroidal field condition.

[1] S. Inoue, Y Ono et al., "Numerical study of energy transfer mechanism of magnetic reconnection/ torus plasma merging under high toroidal magnetic field", to be published in Fusion Energy 2014.

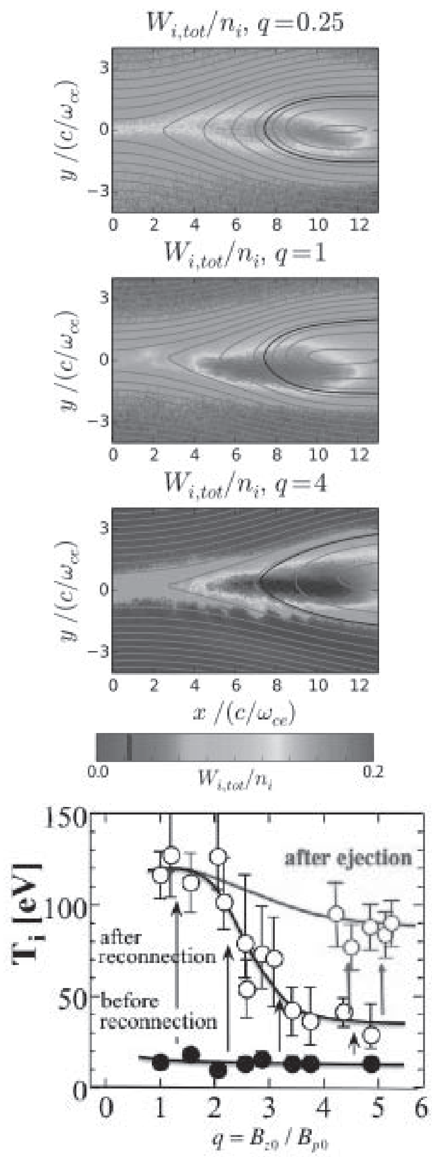

Fig. 1 Top: 2D profiles of ion temperatures (kinetic energies) during reconnection with three different values of *q*=0.25, 1, and 4 in the PIC simulation. Bottom: Ion temperature T_i before and after the reconnection and that after sheet (density) ejection as a function of q in the TS-3 experiment.