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Investigation of fine structure formation of guide field reconnection during merging plasma startup of spherical tokamak in TS-3U

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We present the latest results of high-resolution 2D imaging measurement of merging/reconnection heating during the central solenoid (CS)-free plasma startup of spherical tokamak using a new 96CH 2D ion Doppler tomography diagnostics. In the last decade, magnetic reconnection research made a major progress such as (a) achievement of ∼1keV plasma heating in MAST both for ions and electrons, (b) demonstration of B_{rec}^2 scaling of ion heating ranging 0.01keV < T_i< 1.2keV with 0.01T< B_{rec} < 0.15T in many plasma merging experiments based on outflow heating mechanism and (c) elucidation of fundamental heating characteristics: localized electron heating around X-point mostly by current sheet dissipation and global ion heating downstream where kinetic energy of outflow jet dissipates. Namely in the last three years, it was found that reconnection heating forms fine structure under high guide field condition of B_t > $3B_{rec}$. From 2017, the formation process of the fine structure has been investigated in TS-3U ($B_t \sim 5B_{rec}$) with direct measurement of magnetic field profile and high-resolution 2D imaging measurement of ion temperature profile using a new 96CH ion Doppler Tomography. As a new finding, it was found that ion temperature increases inside the current sheet as well as downstream. The high temperature region around the X-point is affected by Hall current j_{Hall} from the decoupling of ions and electrons, the characteristic heating profile rotates poloidally toward $j_{Hall} \times B_t$ direction. This characteristic is clearer in high field side (B_t depends on major radius in tokamak configuration) and with higher mass ratio (enhancement of $j_{Hall} \times B_t$ due to the larger scale length than current sheet width). While at the end of merging, ion heating downstream is surrounded by closed flux surface formed by reconnected field lines and forms another fine structure. The high temperature profile downstream propagates vertically and finally forms poloidally double-ring-like structure under the influence of better toroidal confinement with higher guide field which strongly suppresses perpendicular heat transport ($\chi^{\parallel}/\chi^{\perp} \sim$ 2$(\omega_{ci}\tau_{ii})^2$»10).

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