Plasmoid oscillation and ion heating through magnetic reconnection during coaxial helicity injection on HIST

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For fusion reactors, non-inductive current drive methods, such as various helicity injection techniques and subsequent RF- or neutral-beam injection are required for steady-state operation. Transient-CHI (T-CHI) non-inductive plasma start-up method could realize compact reactor designs based on the spherical tokamak (ST) without the central solenoid coil. This method needs the magnetic reconnection at the X point for generating a high quality closed flux during the plasma injection phase. The magnetic reconnection is well known to heats effectively ions by converting from magnetic energy to kinetic energy. The application of reconnection heating can be expected for the T-CHI. At present, one of the most important issues in the T-CHI is whether it can establish enough closed flux surfaces and plasma heating by driving the magnetic reconnection as fast as possible.

The key role of plasmoid-mediated magnetic reconnection has been experimentally investigated during T-CHI for non-inductive plasma start-up on Helicity Injected Spherical Torus (HIST: R=0.30 m, a=0.24 m, A=1.25). The fast magnetic reconnection is required for the flux closure in T-CHI discharges. Here, we have found that, (i) during the helicity injection phase, an current sheet is elongated and broken apart at some points inside it due to a tearing instability, leading to the generation of multiple small-size plasmoids. The magnetic helicity is injected from the gun to plasmoid that relaxes to the minimum energy state through magnetic reconnection. After that, during the decay phase, one or two of the plasmoids grow up a large-size plasmoid, i.e. formation of closed flux. (ii) Doppler ion temperature has increased from 10-20 eV up to 80 eV during the T-CHI. The ion heating through the plasmoid reconnection represented as an evidence of the observed oscillation of magnetic field and electron density has been for the first time identified on HIST.

In summary, the experimental investigation has revealed the process of plasmoid-driven magnetic reconnection during T-CHI on HIST. The experimental findings are as follows; (1) the division and coalescence process of plasmoids are repeated after the elongated current-sheet becomes unstable. (2) the ion heating is enhanced due to repetitive reconnection during the plasmoid oscillation.