Studies of Transient CHI Plasma Start-up on HIST

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An advantage of the Spherical Torus (ST) is the low aspect ratio and so elimination of a central solenoid coil is required for attractive high-beta fusion reactors based on the ST concept. Thus alternate methods for the plasma start-up that do not rely on the central solenoid are necessary for the viability of the ST concept. The transient coaxial helicity injection (T-CHI) without requiring for dynamo is a promising candidate for the non-inductive plasma start-up. So far, the T-CHI method has been successfully applied to NSTX for the start-up followed by inductive ramp-up. This coupled discharge has now achieved plasma currents larger than 1 MA [1].

We have recently examined the T-CHI method on the Helicity Injected Spherical Torus (HIST) device [2]. Understanding the physics of the flux closure during T-CHI still remains as a key issue, which is the primary purpose of the experiment on HIST. In the experiment, the internal magnetic field measurements (2D flux plots) have verified the plasmoid injection and the following formation of the closed flux surfaces (flux closure) during the start-up phase. The formation of an X-point after bubble burst has been generated by fast magnetic reconnection event. The MHD simulation [3] on T-CHI suggests that the faster reconnection times compared to the resistive time are consistent with the Sweet-Parker model. The closed poloidal flux increases as increasing the injection voltage. However, after the formation, the current injected continuously from the gun distorts helically the open field lines due to onset of the n=1 kink instability. The electron density decreases rapidly as the instability is triggered. The plasma starts to decay after the injection current terminates. During the decaying phase, the inner edge current diffuses toward the magnetic axis and the magnetic configuration relaxes to the axisymmetric state. The current density profile can be controlled by optimizing the bias (injector) flux so that the kink instability does not occur. The ion and electron temperatures have been investigated by ion Doppler spectroscopy (IDS) and double electrostatic probe measurements.

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[2] M. Nagata et al., Phys. Plasmas **10**, 2932 (2003).

[3] F. Ebrahimi and R. Raman, Phys. Rev. Lett. **114**, 205003 (2015).