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Non-Inductive Solenoid-Less Plasma Current Start-up on HIST Using Transient Coaxial Helicity Injection

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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 non-inductive current drive by the CHI had been demonstrated for spheromaks (SSPX) and ST plasmas (HIST [1], HIT-II, NSTX). While this method offers the potential for steady-state current drive, it was found that this approach could not produce the enough amount of the closed flux because it relies on non-axisymmetric magnetic activity to drive current on closed flux region. Unlike the steady-state CHI (edge current drive) where dynamo activity is required to relax the current inward, in transient CHI (T-CHI) only axisymmetric reconnection during plasmoid ejection process from the injector is believed to be adequate for generating a high quality closed flux. The transient 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 [2]. Understanding the physics of the flux closure during T-CHI still remains as a key issue, which is the primary purpose of this paper. Internal magnetic field measurements in a smaller machine make it possible to confirm the generation of closed flux surfaces. Recently, we have for the first time examined the T-CHI method on HIST (R=0.30 m, a=0.24 m, A=1.25) [3]. In this experiment, T-CHI has generated toroidal currents up to ~30 kA under the condition of the presence of closed flux. One of main results is to verify the flux closure after plasmoid ejection by using internal magnetic probes. We have found that the closed poloidal flux increases proportionally with the toroidal current as increasing the injection voltage across the inner and outer gun electrodes. The plasmoid injection and reconnection time of ~0.025 ms is much faster than the resistive time scale.

[1] M. Nagata et al., 24th IAEA Fusion Energy Conference, ICC/1-1Rb (2012).
[2] R. Raman et al., Phys. Rev. Lett., 104, 095003 (2010).
[3] M. Nagata et al., Phys. Plasmas 10, 2932 (2003).

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