TANGENTIAL INJECTION OF COMPACT TORUS FUELING IN THE HL-3 TOKAMAK USING THE HL-CTI INJECTOR

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Compact torus (CT) injection is one of the most promising approaches for deep fueling in future magnetically confined fusion devices. The CT plasmoid, as a self-organized plasma structure with inherent current confinement, maintains a minimum-energy Taylor state, ensuring its long-lived existence. With strong electromagnetic acceleration, the CT plasma can achieve high velocities without disruption by intense Lorentz forces, allowing them to penetrate deep into magnetized plasmas in strong magnetic field regions. Beyond fueling applications, the high directional velocity of CT plasmoids makes them a valuable tool for plasma momentum injection studies. Recently, we have developed and implemented a high-speed compact torus injector, HL-CTI, on the HL-3 tokamak at the Southwestern Institute of Physics (SWIP). This tangential compact torus injection system facilitates research on fueling physics and toroidal momentum injection in large-scale magnetic confinement devices. Additionally, this injection method has proven valuable in studying mechanisms related to the confinement improvement and density limit.

In HL-CTI platform experiments, we characterized the injection performance using multiple plasma diagnostics. Fiber laser interferometers measured electron density evolutions in the acceleration region, magnetic probes captured the current structure of the CT plasmoid, and a spectrometer analysed the impurities. The maximum discharge current is over 300kA for both the formation and acceleration power supplies. We employed the time-of-flight method to estimate critical injection parameters, including radial velocity, injected mass, total injected particle count, and CT axial momentum. The maximum radial velocity, injected mass, total particle amount, and momentum were measured to be 200km/s, 300μg, 10^{20} and 0.06Nsec, respectively. These precise estimations establish an essential experimental foundation for subsequent fueling and momentum injection studies.

Figure 1. The HL-CTI compact torus injector.

Following the initial platform tests, the HL-CTI injector was tangentially installed on the midplane port of the HL-3 tokamak, as shown in Figure 2, with an injection angle of 22 degrees. Under optimal conditions, the total injected particle amount can reach 20% of the HL-3 particle inventory, and the injected toroidal momentum can contribute up to 10%~20% of the total toroidal momentum. These injections have successfully driven the

plasma density near the density limit. Furthermore, in several discharges, modulating the toroidal momentum has led to improved plasma confinement properties. The full experimental results and their implications will be presented in detail in the report.

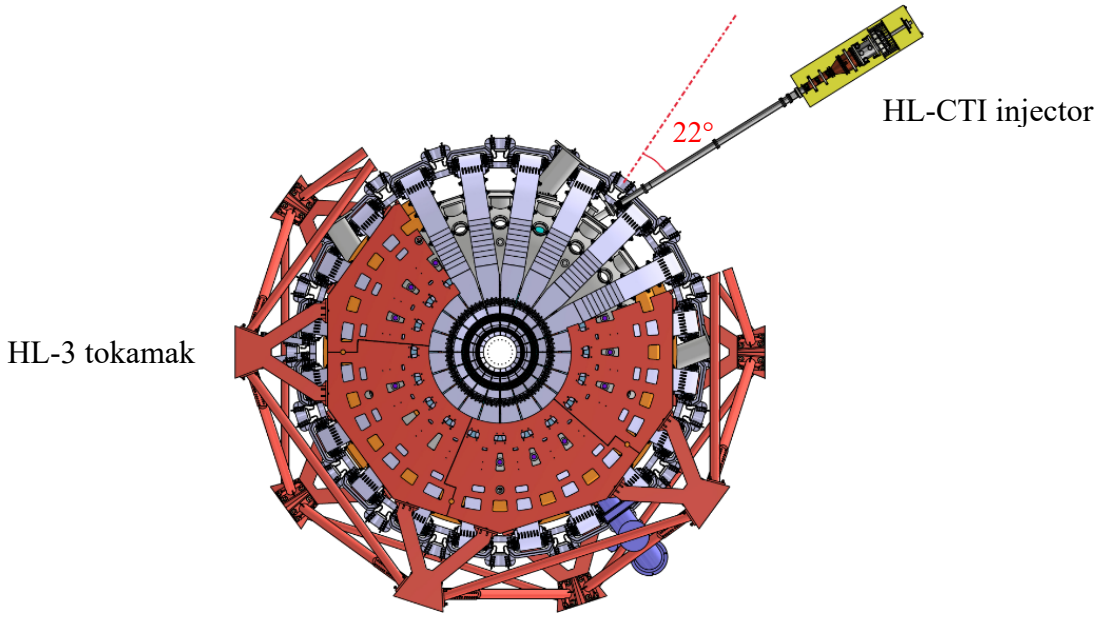

Figure 2. The layout of HL-CTI on the HL-3 tokamak.

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