§85. Optimization of High Density ST Plasma Production by CT Injection in QUEST

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An advanced fueling method of compact torus (CT) injection for spherical tokamak (ST) has been studied in the QUEST device. A ST plasma is magnetically confined at the lower toroidal fields of B_T= 0.25 T for a steady-state mode and B_T= 0.5 T for a pulse mode than conventional tokamaks. The CT injector (UH-CTI) installed on the QUEST has a sufficient performance to penetrate into a tokamak plasma at B_T= 0.8 T. The injector can thus deposit fuel particles deeply in the ST plasma. The primary aim of the experiment is to produce a high-density ST plasma by CT injection fueling. The experiment is also planned to explore possibilities to control CT penetration depth and particle deposition point by varying CT parameters, to study interaction between a high-temperature plasma and a CT plasmoid (magnetic reconnection, helicity conservation, excitation of waves), and to investigate ability of CT injection to assist ST plasma current start-up.

In the experiment, the CT injector is typically operated at the charging voltages of 12 kV to 17 kV, and 25 kV for the CT formation and acceleration banks respectively. In ST plasmas, electron temperature and density profiles can be observed by the Thomson scattering system developed by the University of Tokyo group. In the last fiscal year, it was found that although the internal clock of the Thomson laser system had sufficient accuracy for a 10Hz operation, it was not the order of microsecond required to investigate the fast CT fueling process. The external clock of the laser system and the trigger system needed micro-second accuracy to measure a density profile change due to CT injection. These systems were modified to synchronize the actions of the CT injection and the Thomson scattering.

In this fiscal year, CT injection was conducted to optimize the experimental conditions for effective and efficient fueling in ST plasmas. Plasma responses to a CT injection has been observed in Ohmic heating (OH) ST plasmas with RF power injection. Figure 1 shows plasma responses to a CT injection in an OH-ST plasma. Plasma current has no adverse effect of CT injection. A line averaged electron density increases just after CT injection. Thus the non-disruptive CT injection is successfully made. The electron density and temperature profiles were also observed with the modified Thomson scattering system. Changes due to CT injection in the profiles are shown in fig.2 for the same shot as fig.1. At the fast time of 0.5ms after CT injection, increment in electron density is observed on the peripheral channels. The line averaged electron density is continuously increasing after the profile change as shown in fig.1(c). The deposited CT particles diffuse toroidally at the sound velocity along the magnetic field line and equilibrate on the surface. The equilibrium time is roughly estimated to be 50~100μs for the central fueling and 1.4~2ms for the peripheral in the experiment. This indicates that a CT plasma penetrates into the outboard/inboard edge in an OH-ST plasma and its fuel particles are deposited in the peripheral region. The number of the total deposited particles is, however, less than a predicted one due to CT injection. In the CT experimental setup, a drift tube (0.52 m in length) is installed between the QUEST and the CT injector. The presence of the tube might affect the CT plasma parameters, resulting in loss of CT fueling. We also measured CT electron density at the end of the drift tube to verify the adverse effect. As a result, the electron density decreased to be about 70% of that at the muzzle of the CT injector. The density might decay to be less than 50% on the separatrix of a ST plasma at a CT speed of 200 km/s. In order to improve CT fueling efficiency in ST plasmas, we intend to optimize CT parameters and QUEST conditions.

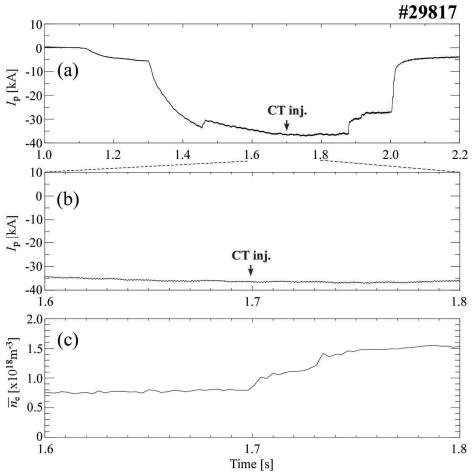
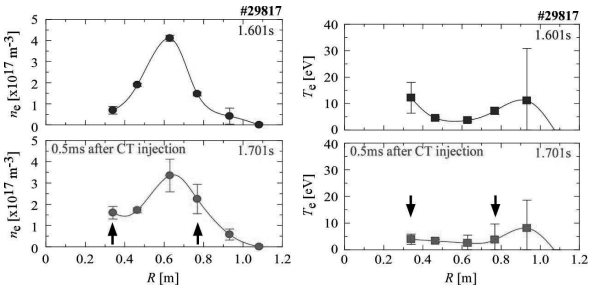


Fig.1. Plasma responses to CT injection in an OH-ST plasma. (a) Plasma current and (b) its time-expanded trace between 1.6s and 1.8s, (c) line averaged electron density with a μ-wave interferometer measurement.



(a) n_e profiles (b) T_e profiles

Fig.2. Electron density and temperature profiles response to a CT injection in the same shot as fig1.