§15. Analysis of Particle Flux in Long Pulse Discharge in LHD

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Particle behavior during a long pulse discharge is an interest subject for a steady state operation. The amount of supplied and exhausted particles is estimated for the long pulse discharge accomplished by ECH and ICRF heating.

Time evolution of the plasma parameters of analyzed shot is shown in Fig. 1. An ICRF power of 0.8 MW and an ECH power of 0.4 MW are injected, and the plasma duration time is about 5 minutes. Helium gas is supplied by gas puff. Hydrogen gas is also injected by super sonic gas puff (SSGP) system. A line-averaged electron density of 1.3×10^{19} m^{-3} is kept and central electron temperature is about 2 keV during the shot.

At first, we tried to estimate the amount of supplied particles. For the estimation of inlet flow by gas-puffing, we used the voltage of the piezo actuator, which drives the valve of the gas injector. The piezo voltage is associated with the flow rate by the calibration using short pulse injection. However, for the long pulse injection, the flow rate gradually reduces even if the same piezo voltage is applied. Then, we measured the actual flow rate using the recorded piezo voltage. We assumed the same amount for helium and hydrogen gas. Total amount of the supplied helium gas by gas-puffing is 29.18 Pam^3 by an average of three times of the measurements.

For the SSGP injection, we used the data of one injection and summed up by the number of times of SSGP injection. The amount of supplied hydrogen as by one injection is estimated to 0.6 Pam^3. The number of injection times is 271 judging from the behavior of the peripheral channels of FIR signals. Then, total amount of hydrogen gas by SSGP injection is estimated to 162.6 Pam^3.

Next is an evaluation of evacuation amount by the vacuum pumping system. The exhaust speed is assumed same as the specification value. Degree of vacuum is converted to the case of the helium gas. Then, total evacuation amount by the vacuum pumping system is estimated to 17.4 Pam^3.

Particle balance in the vacuum vessel is assumed to express by following relation.

$$dN_p/dt + dN_0/dt = \Gamma_{fuel} - \Gamma_{pump} - \Gamma_{wall}, \quad (1)$$

where N_p is a number of ions in the plasma, N_0 is a number of neutral atoms in the vacuum vessel. Γ_{fuel}, Γ_{pump}, and Γ_{wall} are fueling rate, pumping rate, and net wall pumping rate, respectively. The estimated inlet and evacuated amounts are converted to a number of atoms. Figure 2 shows a time-integrated number of atoms supplied and exhausted during the five minutes discharge. Hydrogen ion ratio obtained by spectroscopy is also plotted. Despite a large mount of gas is injected, the electron density keeps constant as shown in Fig. 1. Especially a huge amount of hydrogen is estimated to injected by SSGP. Spike of hydrogen ratio in Fig. 2 is related with the hydrogen injection by SSGP. Evacuation by the vacuum pumping system is very small in comparison with the total supplied gas. The vacuum vessel wall works as a pump in this pulse length of the discharge. We will investigate the longer pulse discharge whether the vacuum vessel wall turns to source of gas.

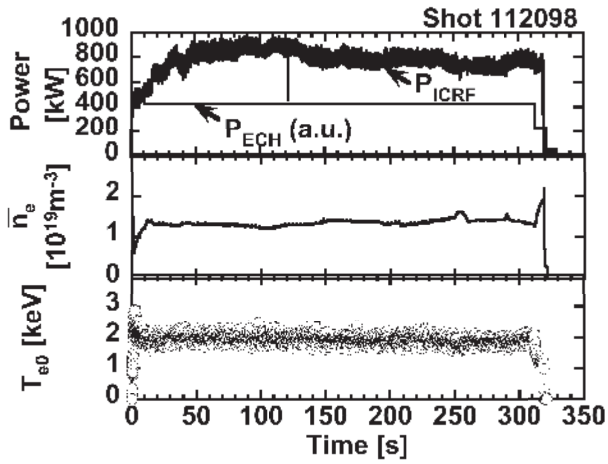

Fig. 1. Time evolution of the plasma parameters for the analyzed five-minutes operation. Injected power, line-averaged electron density, and central electron temperature are plotted from top column.

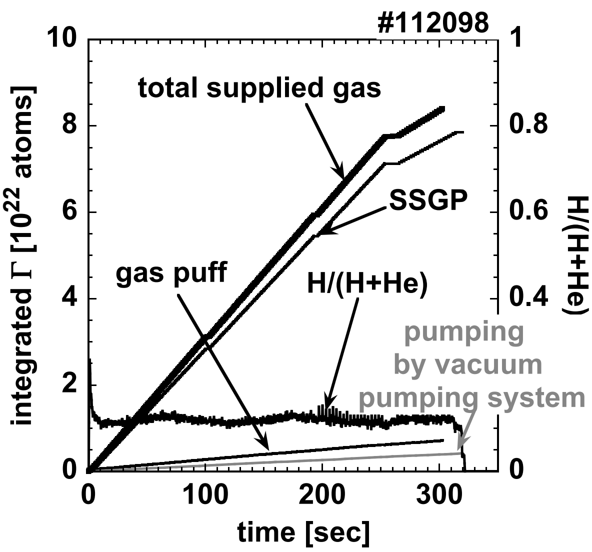

Fig. 2. Estimated amount of flow during the five-minutes operation. Supplied amount of gas puff and SSGP, total supplied amount, and evacuated amount by the vacuum pumping system are plotted. hydrogen ion ratio is also plotted.