§5. Particle Balance Analysis in Long Pulse Discharge in LHD

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In steady state operation, particle balance is a very important subject. In a short pulse operation, plasma density is controlled easily by changing of an amount of fueling. However, in a long pulse operation, particle behavior is quite different from that of a short pulse operation and the density control must be carried out in a different manner. Vacuum vessel wall plays an important role for density control in a long pulse operation as a fueling and pumping. Particle balance analysis shows a role of the wall in the steady state discharge.

The analysis was carried out in the discharge shown in Fig. 1. This is the longest shot achieved in the power level of MW and the density of $1x10^{19}$ m^{-3}. An ICRF power of 0.7 MW and an ECH power of 0.3 MW were injected. Reduction of the ICRF power was occurred during the injection by operation of the interlock system, which was attribute to the influence from the plasma to the ICRF antenna. Fluctuation of divertor temperature was caused by the sweep of the magnetic axis. During the discharge, supersonic gas-puffing (SSGP) injected the hydrogen gas. However, hydrogen ratio did not changed so much during the discharge. Around 820 and 950 seconds, fueling was stopped to reduce the density. After that, the density decreased and we had to restart the fueling to keep the density higher than $1x10^{19}$ m^{-3}.

First of all, the amount of supplied particles by gas-puffing was estimated. We used the voltage of the piezo actuator, which drove the valve of the gas injector. In a long pulse operation, the flow rate is gradually reduced and different from that of the short pulse operation. Then, we used the calibration rate obtained by the long pulse test and offset value of the voltage was assumed to be no flow. We assumed the same amount for helium gas and hydrogen gas though the gas-puffing fuels helium gas.

Secondly, we estimated the amount supplied by the SSGP. The SSGP fueled the hydrogen gas and the fueling rate was estimated to 0.08648 Pam^3 per injection in this discharge. The injection time was estimated from the behavior of the density. The total injection was 994 times.

Next, evacuation amount by the vacuum pumping unit was estimated. Helium was dominant in partial pressure, so degree of vacuum was converted to the case of the helium gas. Exhaust speed was estimated by the test of the vacuum pumping unit.

The estimated inlet and evacuated amounts were converted to the number of atoms. Figure 2 shows the time-integrated number of atoms supplied and exhausted during the 19 minutes discharge shown in Fig.1. A large mount of gas is injected to keep the electron density constant. SSGP injected more amount of hydrogen than amount of helium fueled by the gas-puffing. Evacuated amount by the vacuum pumping unit is very small in comparison with the total supplied gas. The vacuum vessel wall still remains working as a pump though the density increased without fueling on the way during the discharge. We have the plan to estimate the fueling by gas-puffing more accurately using a mass flow meter in the next experiment.

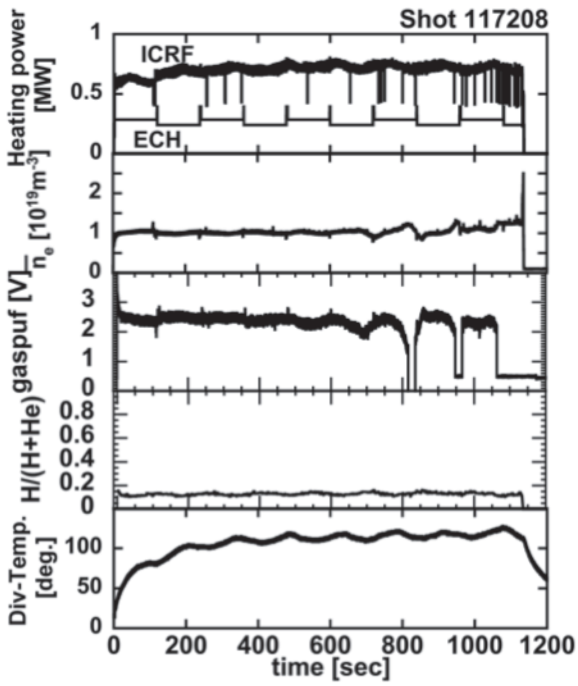

Fig. 1. Time evolution of the plasma parameters for the analyzed discharge. Injected power, line-averaged electron density, gas-puff voltage, hydrogen ration, and divertor temperature are plotted from the top column.

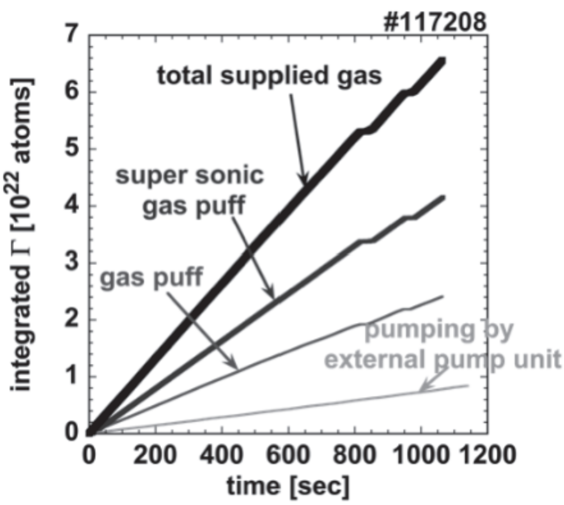

Fig. 2. Estimated amount of flow during the 19 minutes discharge. Supplied amount of gas-puffing and SSGP, total supplied amount, and evacuated amount by the vacuum pumping unit are plotted.