§2. Gas Fueling and Particle Exhaust Behavior for Steady-State Operation in the LHD

Kasahara, H., Yoshimura, Y., Tokitani, M., Ashikawa, N., Nagasaki, K. (Institute of Advanced Energy, Kyoto Univ.), Ueda, Y. (Osaka Univ.), Seki, T., Saito, K., Nomura, G., Seki, R., Mutoh, T., Kobayashi, M., Yasui, K., Suzuki, N., LHD Experiment Group

Using radio-frequency (RF) heating, stable long-pulse operations are demonstrated on the Large Helical Device (LHD), and it suggests that the helical concept can easily sustain stable plasma than tokamaks. The long-pulse operation for one hour was demonstrated in 2006 with the line averaged electron density n_e of 0.4×10^{19} m^{-3}, central electron temperature T_{e0} of 1.3 keV and the averaged heating power P_{rf} of 0.5 MW (ICH:0.4MW+ECH:0.1MW) for hydrogen minority heating scenario of the helium plasma. At this discharge, the electron density could be controlled by the feedback system using piezo-valve, and the gas-fueling ratio was not sensitive for heating injection power.

In 2012, in order to foresee the large particle and heat fluxes to divertor and wall at the steady-state fusion reactor, we have challenged to realize higher-performance steady-state discharge. The steady state plasma of discharge length of 18 min. 55 sec. with n_{e0} of 1×10^{19} m^{-3} and T_{e0} of 2.5 keV was achieved by P_{rf} of ~1MW (ICH:0.7MW+ECH:0.24MW). Figure 1(a) shows time evolution for hydrogen and helium pressure measured by quadrupole mas-spectrometry, which is installed close to exhaust system at 6-O port, and the plasma discharge is sustained on the shaded area. But magnetic axis sweeping causes weak fluctuations for Fig. 1(c) ~ (d), neutral pressures (P_{cc}) at several outside ports in the vacuum vessel, divertor temperature and helium pressure are approximately constant during long-pulse discharge in #117208. The hydrogen pressure is too small than the helium pressure, and the increment in hydrogen pressure can be negligible. However, in order to keep electron density after 800 sec, precise gas-fueling control is needed with small fueling ratio, and we have to consider the effect of time evolution for the gas-fueling ratio on the high-performance long-pulse discharge. Figure 2 shows the time evolution for neutral (P_{cc}), helium (He) and hydrogen (H) pressure just after plasma discharge, and there are two time-scales, short(T_1) and long(T_2) , on the logarithm plots for pressures. If T_1 is much smaller than T_2, time dependences of the pressure $C_{Pressure}$ is given by

$$C_{Pressure}(t) = C_0 + C_1 \exp(-t/T_1) + C_2 \exp(-t/T_2), \quad (1)$$

where C_0, C_1 and C_2 are constants in each kinds of particles. If the C_1 is much lager than the C_2, the third term of eq. (1) is negligible on the beginning phase. On the other hands, the second term of eq. (1) goes to zero on the late phase, and two kinds of slopes are appeared on the logaritm plot. The time-scale of T_1 is approximately 100 sec., and it is similar to the time-scale of decrement in the divertor temperature (~ 150 sec.). Divertor with higher temperature than the ambient temperature is one of the candidates for particle sources to vacuum vessel just after long-pulse discharge, and the slope of hydrogen is slightly larger than that of helium.

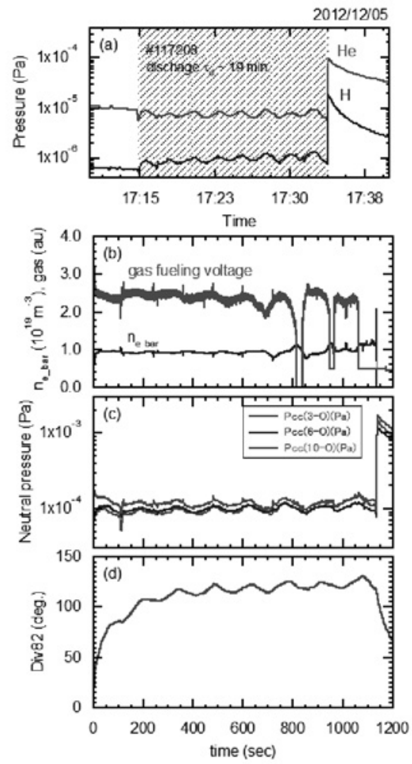

Fig. 1. Hydrogen and helium pressure, gas fueling, line averaged electron density, neutral pressure (P_{cc}) and divertor temperature during the long-pulse discharge.

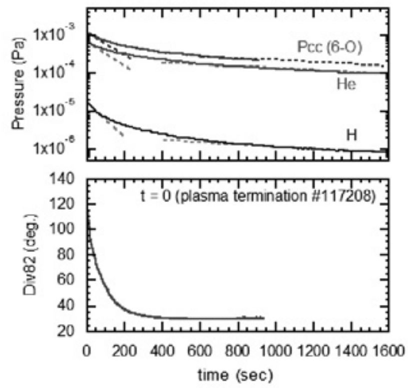

Fig. 2. Time evolution for pressures and divertor temperature in the vacuum vessel just after high-performance long-pulse discharge.