29SI-2

球状トカマクに於ける粒子制御と定常プラズマ放電
Control of wall recycling and Steady State Tokamak Operation in QUEST

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Steady State operation

The steady state operation of ST plasma is not only one of the missions of the QUEST projects, but also is required as the minimum performance of a key device in the frame work of the bilateral collaboration. At least three independent but inter-related subjects must be resolved; (1) the current drive performance, (2) heat balance on the PFCs and (3) global particle balance in the system.

In the typical discharge (#19674) P_{rf} of 50 kW was used to drive high β_p plasma at I_p of 10 kA, as shown in Fig.1. Hard X-rays measured along the co(anti parallel to the I_p direction), counter, and perpendicular directions show the steady state sustainment of the energetic electrons. Although the HX fluxes are remained almost constant, energy spectra are quite different (not shown). The Energy of X-rays emitted from the co-moving electrons reaches ~ 1MeV, but that from counter-moving ones is limited below 0.4 MeV. Two perpendicular ones are between them. Unfortunately the density could not be measured. The series of puff were used to keep the pressure a certain value (3×10^{-6} Torr) inside the chamber, but it stopped at 90 sec. If the gas puff was continued further, the pressure increased and then I_p was reduced below 10 kA. H_α increased until 90 sec, and then remained a certain value, indicating constant global PWI. However, a small change in the surface temperature of the movable forced cooled guard limiter made of W was found at 90 sec, which indicated a local change in PWI. On the horizontal plane four guard limiters are located at 65 mm from the wall(R=1400 mm). Since these Mo plates (W=50 mm and H=220 mm) are not cooled, the surface temperature limits the present SSTO duration. Local power deposition, which is considered as a consequence of the local loss of energetic electrons on particular PFCs, causes an abrupt surface temperature rise or melts them. In the next campaign cooling performance will be upgrading.

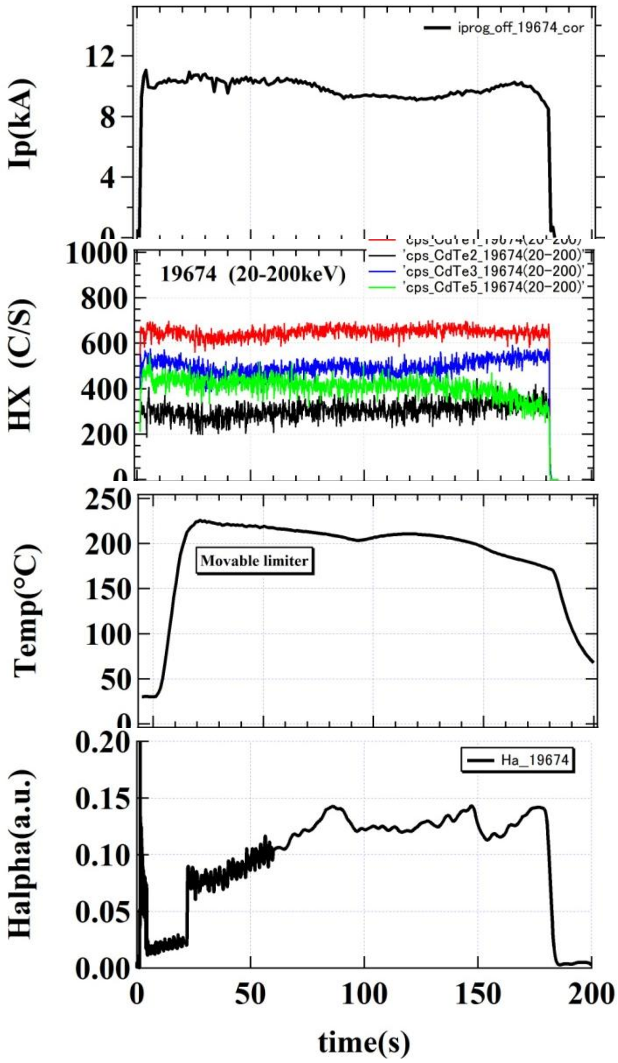

Fig.1 Time evolution of SST plasma; (a) Ip, (b) HX (co-red, vertical-blue, vertical-green, ctr-black), (c) temerature of the movable limiter, (d) Hα from the CS region.

Global particle balance

In order to demonstration SSTO, the global particle balance must be well understood and controlled. Two subjects for working gas H_2 have been investigated in relatively low density plasma; (1) global balance between fueling and external pumping, and (2) wall pumping and release. The volume of the chamber and extension pumping port is 12.8 m^3 and the surface area of the plasma facing components is ~ 35 m^2. The one third of the PFC is tungsten and the rest is SS. No active coating of light materials is done. Two cryogenic pump and one TMP are used to exhaust H_2 at pumping speed of 2.7 m^3/sec. The gas is fuelled by a piezo unit whose fueling rate is controlled by the width and the number of voltage pulses. The pressure inside the chamber is measured by an ionization gauge and the partial gas components are measured by a residual gas analyzer near the TMP head. The recycling is monitored by several spectroscopic instruments.

The global particle balance in SN 19674, as shown in Fig. 2, is analyzed as follows;

1) Q_{fuel}: total fueled particles at almost constant fueling rate of 2.5×10^{17} H_2/s for 90s ~2.2×10^{19} H_2

2) $Q_{pumped}(T_d)$: pumped particles for the discharge duration of T_d=180s is 1.3×10^{19} H_2 ~$0.6\times Q_{fuel}$

3) At 34 sec after the discharge has been terminated, $Q_{pumped}(T_d+34s)$ equals to Q_{fuel}, and then $Q_{pumped}(4T_d=720\ s)$ reaches $4.5\times Q_{fuel}$.

Thus, QUEST results show that 1) the metal wall pumping dominates the global particle balance during the discharge, and then 2) enhanced particle release just after the termination of the discharge recovers Q_{fuel} within ~ 30 sec. In order to understand the unbalanced condition that Q_{pumped} is $4.5\times Q_{fuel}$ during the interval duration, the discharge history has to be investigated further. For previous long pulse discharges(total 400s duration in SN 19668-19673) the total sum of Q_{fuel} is only $5.8\times Q_{fuel}$(SN19674).

Pumping of He

In addition to the H2 global balance, the wall pumping and release of He is also examined. The total pumping speed is ~ 1.9 m^3/sec. The He signal of RGA with(solid) and without plasma(dotted) are shown in Fig.3. The valves are open at 80 s and the discharge duration is 20 s. The difference between two is also shown in the lower figure. The He is wall pumped at the constant rate for 20s and then He is released for 40 s. After that release rate is much reduced. Thus even during the interval, 2/3 of Q_{fuel} is retained in the metallic wall.

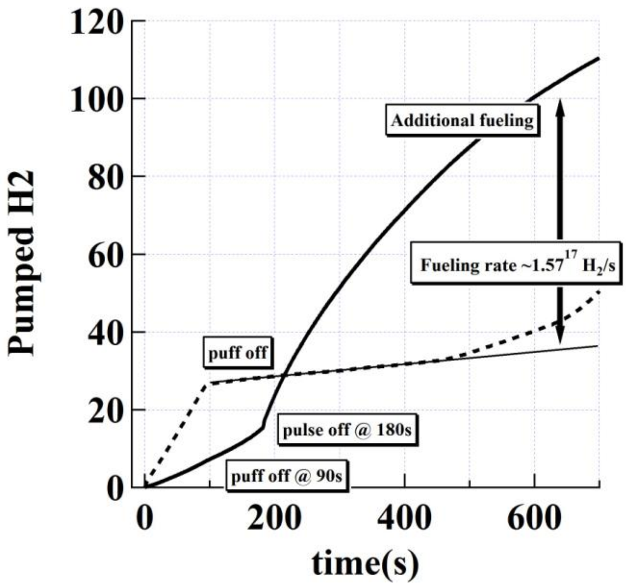

Fig. 2 Global gas balance for #19674(180s discharge). The puff was stopped at 90 sec.

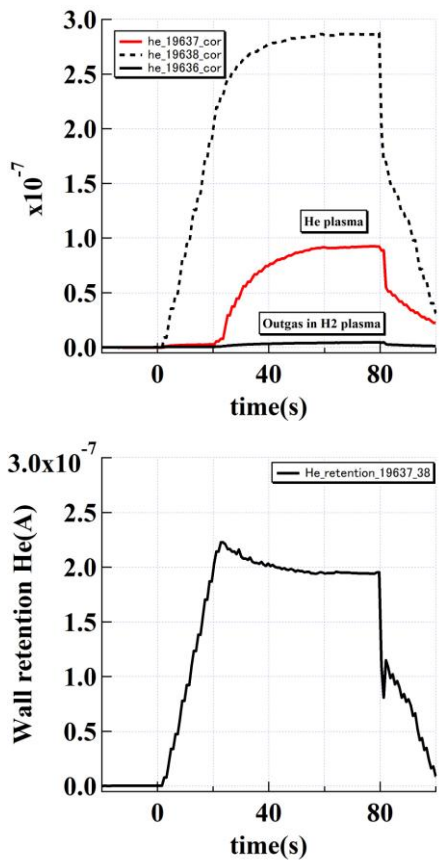

Fig. 3 Global gas balance for #19637(20s duration). The He puff was done during the pulse. All valves are closed.