§68. Steady State Non-inductive Plasma Operation and Particle Recycling under the Hot Wall in QUEST

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The steady state operation driven by electron cyclotron waves has been demonstrated in QUEST. Achieved parameter regime is shown in Fig. 1.

28 GHz Electron Cyclotron Current Drive (ECCD) effect was clearly observed in Ohmically heated plasmas with feedback regulation of center solenoid coil current in 2nd harmonic inboard off-axis heating scenario. In non-inductive current drive experiments only by the 28 GHz injection, 54 kA plasma current was sustained for 0.9 s. Higher plasma current of 66kA was non-inductively obtained by slow ramp-up of vertical field using the 28 GHz ECH/ECCD. Non-inductive high-density and current plasma start-up, which is a key issue for fusion reactor design, has been demonstrated using 2nd harmonic ECH/ECCD. Density jump across 8.2GHz cutoff density was observed in superposed 28GHz and 8.2GHz injections. The 50kA plasmas were sustained by the 8.2 GHz injection into the 28GHz target plasma if the stable plasma shaping was obtained [1].

Successful production of high βp plasma ($\varepsilon\beta p \geq 1$) and its long pulse sustainment by fully non-inductive (NI) current drive with the help of a modest power (< 100 kW) Electron Cyclotron Waves is demonstrated. We found that (i) high βp plasma is naturally self organized to form a stable natural Inboard Poloidal field Null (IPN) equilibrium, (ii) a critical βp, which defines the transition boundary from Inboard Limiter (IL) to IPN equilibria and (iii) a new feature of plasma self organization to enhance its negative triangular shape to sustain high βp. This result shows a relatively simple method to produce and sustain high βp plasma close to the equilibrium limit in a stable configuration exploiting its self-organization property. Furthermore, spontaneous toroidal rotation is observed in IPN configurations as well as open magnetic field line under high magnetic curvature, which is sustained in steady state for the entire plasma duration [2].

Progression from low (LR) to high recycling (HR) was observed in full non-inductive long duration discharges up to 5 minutes on QUEST. Transitional repetitive behavior between LR and HR was induced by periodic gas puffing and the period to recover to LR, τ_{rec}, was gradually prolonged. The period, τ_{rec} normalized by gas rate has a linear relation to time-integrated H_α. As the prolongation of τ_{rec} was also induced by higher gas rate even in the start-up phase, the value of τ_{rec} is an index of the amount of recycled hydrogen. The experimental observation indicates hydrogen recycling rate is dominantly depending on hydrogen fluence to the wall. To understand the dependence, deuterium storing capability of the specimen exposed to QUEST plasmas during an experimental campaign was investigated by implantation of deuterium molecule ions of 1keV and subsequent thermal desorption spectrum (TDS) as a post-mortem analysis. The important desorption in the obtained TDSs appeared around 420 and 470K, and these peaks can be reconstructed by a model including diffusion, recombination, trapping, and plasma induced desorption. The model calculation was applied to the QUEST long duration discharges and shows that recycling ratio has a clear dependence on fluence and the fluence in the QUEST long duration discharges is sufficient to make a saturation in recycling ratio of unity. These results indicate that hydrogen recycling has the capability to provide a clear effect on plasma in long duration discharges and the progression is driven by enhanced hydrogen recycling with high fluence to the wall [3].

The global gas balance in the various types of steady discharges has been re-examined by measuring the partial pressures of hydrogen and helium, and plasma induced permeated flux at various positions. A new approach to study the dynamics of particle circulation in steady state tokamak operation SSTO has been proposed and demonstrated in QUEST with all metal walls baked at 100°C. Using perturbations of particle source H2 and plasma-wall interaction PWI the system functions of processes of retention and release into/from the wall are determined both in time and frequency domains. The time dependent probability function of the transition between high and low recycling states has been derived [4].

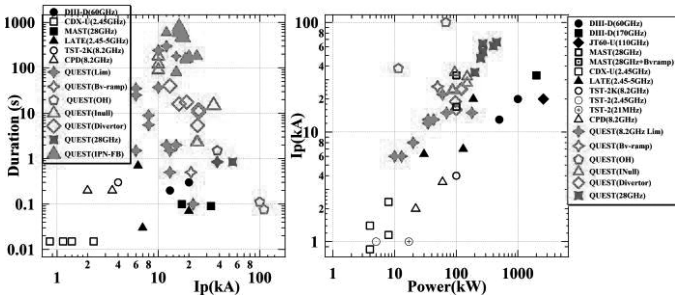

Fig.1(a) Discharge duration vs. Ip,(b) Ip vs. rf power.

[1] H. Idei ,et al, 23rd FEC
[2] K. Mishra, NF 2015 (online)
[3] K. Hanada, et al., 23rd FEC
[4] H. Zushi, et al., 23rd FEC