§6. Hydrogen Steady State Operations and Particle Balances

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The operational scenario of long pulse discharges is important issue in Large Helical Device (LHD). As a superconducting device, LHD is suitable for studying the physics and technology of steady-state operation, such as heat flow balance, particle balance, plasma–wall interaction and physics of heating technology [1]. Current steady-state plasmas are supported by ion cyclotron range of frequencies (ICRF) heating systems and then main working gasses is used helium. For example, the steady-state plasma of 1135 sec. with n_e of 1 x 10^{19} m^{-3} and Te of 2.5 keV was achieved by P_{rf} of ~1MW (ICH : 0.7 MW + ECH : 0.24 MW) in the 16th experimental campaign. But an investigation of hydrogen steady state operation is also important related future deuterium plasma in LHD. Because, helium and hydrogen have a different wall recycling and different trapping sites on the plasma facing walls and chemical reactions of hydrogen are known.

This collaboration frame work was started based on "Divertor plasma wall interaction (PWI)" group in the 14-15 experimental campaigns. LHD experimental groups were reorganized in this year and new group, "steady state operation and PWI", are started from the 16^{th} LHD campaign. Then the meeting about "hydrogen steady state operations and particle balance" are planned and discussed in this collaboration.

Topics of this meeting are as followings,

-Introduction
-Experimental plan about steady state operation and plasma wall interactions in the 16th experimental campaign in LHD.
-Wall recycling experiment in LHD and QUEST [2].
-Helium ash experiment and data analysis in LHD.
-Analysis of particle balance using point model in QUEST [3].
-In-situ measurement of hydrogen recycling using permeation probe [4].
-Overview about ITPA integrated operation scenario (IOS) topical group and comments for LHD-SSO experiment.
-Comments for SSO experiment in LHD
-Comments for PWI and diverter physics in consultancy meeting
-Discussion

From discussion in this meeting, important issues are listed.

Required characterization of steady-state operation is not clear in LHD. In tokamaks, three important parameters were determined such as a high current drive efficiency, controlled particle/impurities transport and an aligned for MHD stability. Pulse lengths of long pulse plasma are expanded with these parameters.

The structures of edge plasmas are different between LHD and tokamaks. Responses of particle transport from edge plasma to core plasma are not understood well enough. At long pulse plasmas over 500 sec, wall recycling of fueling gas is increasing and it is measured by the quadrupol mass spectrometry (QMS) and penning gauges. From comparison with neutral gas pressure and spectroscopy, different time responses are observed. And then an investigation about these recycling mechanisms is required. For investigations of particle balances, in-situ diagnostics are also important. One of these diagnostics, permeation probe is presented in this meeting, and monitors of deposition/erosion, thickness of coated layer are discussed. Optimization of spatial resolutions and stored time intervals are needed in current steady-state operation in LHD. In steady-state operation, an interval time between each plasma operation is expanded and settings for data stored data systems are also changed. Spectroscopies worked to observe hydrogen and helium lines for normal operations, but real-time monitor in long pulse discharges are not supported yet. A discussion about important diagnostics with their operational settings is required.

Measurements of the dynamic behavior of hydrogen retention in PFC are extremely difficult in fusion devices due to the difficulty in the in-situ surface analyses. PWI observations show analytical data as static retentions, but dynamic retentions are observed by diagnostics. At present, laboratory-scale experiment of dynamic retention has been done using ion beam analysis [5]. For investigation of global mechanism of total retention, a comparison with modeling and these experimental results is required.

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