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Progress of Steady State Operation Using RF Heating in the LHD

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Plasmas with the improved electron confinement state, electron internal transport barrier (e-ITB), have been investigated with short pulse discharges (< 1 s). Recent upgrade of ECH system enabled the ECH power up to 0.6 MW at the pulse duration longer than a few minutes. Effective on-axis heating with the increased ECH power realized exploration of the possibility of long pulse sustainment of high performance plasmas having e-ITB, without negative effects of impurity accumulation and/or current diffusion. A plasma discharge #122257 (magnetic axis position Rax = 3.65 m, average magnetic field on the magnetic axis Bt = 2.712 T) with the line average electron density ne_ave = 1.1×10ˆ19 mˆ−3 and the central electron temperature Te0 = 3.5 keV was stably sustained for 330 s by ECH power of 340 kW. The Te profile had fine ITB structure, and it was kept stably all over the discharge duration. The discharge #131054 (Rax = 3.6 m, Bt = 2.75 T) was performed with nearly the same ne_ave and ECH power of ˜350 kW, while there was no ITB, and Te0 was 2.7 keV. Calculation of ECH power deposition using TRAVIS code tells that the deposition power density at the plasma center in #122257 (with ITB), 2 MWmˆ−3, is twice higher than that of #131054 (w/o ITB), 0.93 MWmˆ−3. Accumulation of the impurity and increase in radiation power are not recognized in these discharges.
Improvement of ICH system by an additional impedance transformer realized ICH power increment up to 1.5 MW. Keeping the minority hydrogen ion ratio H/(H+He) of plasmas not less than ˜0.1 by repetitive H pellet injection mitigated the acceleration of risky fast hydrogen ions. Without the H pellets, the minority ion ratio tends to decrease by majority He gas fueling. Modification of the structure of divertor plates contributed to the reduction of impurity influx events. In FY 2014, with these improvements, long pulse sustainment at higher density region over 2×10ˆ19 mˆ−3 was investigated. About 2 MW in total of ICH and ECH powers sustained a plasma with ne_ave of 2.2×10ˆ19 mˆ−3 for 8 min, while the former 48 min discharge with ne_ave of 1.2×10ˆ19 mˆ−3 was sustained by ICH and ECH total power of 1.2 MW. So far, out-gas (density increase) and/or occurrence of sparks (intense impurity influx) at the plasma facing components are the main causes of the termination of the long pulse discharges in the LHD.

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