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EX/P2-12: Steady State Operation Using Improved ICH and ECH for High Performance Plasma in LHD

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The steady state operation (SSO) of high-performance plasma in LHD [1] has progressed since the last IAEA conference by means of a newly installed ICH antenna (HAS antenna [2], HAnd Shake type) and an improved ECH system. HAS antenna could control the launched parallel wave number and heated a core plasma efficiently. The heating power of steady state ICH and ECH exceeded 1 MW and 500 kW, respectively, and the higher-density helium plasma with minority hydrogen ions was sustained. Plasma performance improved; e.g., an electron temperature of more than 2 keV at a density of more than 2 x “10ˆ19”“mˆ-3”became possible for more than 1 min. Dipole phasing operation of the HAS antenna is better than that of monopole operation, and the monopole operation gives almost the same performance with the poloidal array antenna [1]. Three 77-GHz high-power gyrotrons were also installed for high-power ECH in LHD [3]. The frequency of 77-GHz is selected to heat the plasma core region for the wider plasma operation condition, and to increase sustainable plasma density to mitigate the high energetic ion population produced by ICRF wave.
The injected power to plasma is finally absorbed by divertor plates, antenna side protectors and the chamber wall. The ratios of heat flow through various channels are estimated and about half of the heat flow goes to the divertor plates, and around 10% is goes to the ICRF antenna protectors. The non-uniform heat flow to the chamber wall decreased from 30% to 15% as the density increased.
The particle balance during SSO was also analyzed. The ratio of the total supplied particles (helium and hydrogen) to the externally pumped particles is around 20, which indicates that wall pumping is a dominant particle sink during the SSO of 320 sec. The vacuum chamber works as a large particle sink in LHD. In the case of 54-min plasma operation in 2006 [1], the LHD chamber wall also worked as a particle sink even after the very long operation time.
These experiences of steady state operation give us useful information for ITER and future fusion devices.

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[2] H. Kasahara, K. Saito, et al., Plasma and Fusion Research, Vol.5, S2090-1-5 (2010)
[3] T. Shimozuma, et al., Fusion Science and Technology, Vol.58, No.12, 2010, pp530-538

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