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KSTAR における電子サイクロトロン波による壁調整の最適なパラメータの決定

Determination of Best Operation Parameters of Electron Cyclotron Wall Conditioning in KSTAR[1]

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QST[1], IRFM[2], KFE[3], SNU[4], GA[5]

Wall conditioning is a key for fuel retention control, for example, tritium control in ITER, where in-vessel tritium inventory is limited to 640 g [2]. Glow Discharge Cleaning (GDC) and Taylor Discharge Cleaning (TDC) have been widely used in normal conducting devices. In superconducting devices, however, a steady-state toroidal magnetic field prevents glow discharge plasma expanding onto plasma facing components, leading to low cleaning efficiency. In contrast, Electron Cyclotron Wall Conditioning (ECWC) and Ion Cyclotron Wall Conditioning (ICWC) are available under steady-state toroidal magnetic field. ECWC at the 2nd or the 3rd harmonic EC frequency is planned in ITER (pre-fusion power operation phase 1) [3] while ECWC at 2nd harmonic is planned in JT-60SA [4].

This study performs a systematic scan of the following parameters ; EC injection power at 0.6 and 1.4 MW (140 GHz, X2), EC injection width between 0.1 and 1.0 s and prefilled He pressure between 3×10^{-5} and 2.2×10^{-2} mbar. First, a normal tokamak discharge at a plasma current of 0.7 MA and a toroidal magnetic field of 2.4 T with EC assist from 0.04 to 0.45 s at a power of 1.4 MW is performed and terminated by SPI. This is to provide the same level of deuterium retention before an ECWC sequence. Second, an ECWC sequence is performed in Trapped Particle magnetic Configuration (TPC). Third, a normal tokamak discharge with the same discharge conditions as above described is performed again. This is to investigate whether the plasma burn-through is successful or not. If successful, this is also to provide the reference level of deuterium retention. Then, an ECWC sequence with different parameters is performed for the parameter scan.

The experiment shows; ECWC plasma density increased by a factor of 4 with increasing prefilled He pressure from 3×10^{-5} and 2.2×10^{-2} mbar, while the maximum D_2 outgas was found at a prefilled He pressure of $\sim 3 \times 10^{-4}$ mbar. Also ECWC plasma density increased by 40% with increasing EC power from 0.6 to 1.4 MW and D_2 outgas amount was higher by a factor of 2 at 1.4 MW compared to that at 0.6 MW. However, EC pulse width was less effective in terms of both ECWC plasma density and D_2 outgas amount.

It was found that the D_2 outgas was correlated with ion flux to the centre stack, which was connected to the EC resonance layer through the magnetic field line. This suggested that ECWC with TPC configuration effectively removed the deuterium retained at the centre stack. In addition, it was found that a shortfall in the D_2 outgas was seen only for ECWC executed after a failed burn-through, suggesting that the shortfall resulted from the D_2 outgas during the CS swing. The shortfall was comparable to D_2 outgas amount by ECWC, thus, this observation suggested that the ECWC D_2 removal efficiency was comparable to that by CS swing.

[1] T.Nakano et al., Nucl. Mater. Energy 33 (2022) 101275. [2] J.Roth et al., Plasma Phys. Control Fusion 50 (2008) 103001. [3] ITER technical report ITR-18-003. [4] JT-60SA research Plan, https://www.jt60sa.org/wp/wp-content/uploads/2021/02/JT-60SA_Res_Plan-5.pdf