Recent progress in improving ICRF power coupling with local gas puffing in EAST

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Radio-frequency (RF) heating with waves in the Ion Cyclotron Range of Frequencies (ICRF) is one of the main heating methods in current and future tokamaks, such as ITER. ICRF relies on the fast wave to transport the wave energy from the antenna at the plasma boundary to the plasma core. However, in the plasma edge, especially in the far scrape-off layer (SOL) right in front of the antenna, there often exists an evanescent layer in which the plasma density is below the fast wave cut-off density (usually of the order of 1E18 m^{-3} for typical frequencies and antenna spectrum in nowadays tokamak). For a given anti-node voltage of the transmission line and the transmission line characteristic impedance, the coupled ICRF power depends exponentially on the evanescent distance (d_{evan}) from the antenna to the cut-off density, i.e. $P_{coupled} \propto R_c \propto R_0 e^{-\alpha k_\parallel d_{evan}}$, where R_c is the coupling resistance, α is the tunneling factor and $k_\parallel$ is the parallel wave vector [1]. Thus, by increasing the plasma density in front of the antenna, the evanescent distance can be made smaller and the ICRF power coupling can be increased.

The edge plasma density can be effectively increased by puffing the fueling gas locally in the main chamber of the machine. Previously, great efforts, both experimentally and numerically, have been made in the study of maximization of ICRF power coupling with local gas puffing in many devices, such as ASDEX Upgrade (AUG) [2-6], JET [7-9], DIII-D [10, 11]. In recent years, plenty of experiments on EAST have been carried out to characterize the effects of local gas puffing on edge plasma density and ICRF coupling [12, 13]. The results indicate that with a deuterium gas injection of 8E20el/s next to the B-port antenna, the increase of local density leads to a decrease of evanescent distance by 2-3cm. The coupling resistance of B-port antenna increases from 2Ω to 3.5-4Ω (i.e. by 75%-100%). In the meanwhile, the I-port antenna, which is located toroidally 157.5° away from the I-port antenna, also increases the coupling resistance by 20%. This is because the local gas valves are radially not far away from the seperatrix, part of the gas could penetrate the SOL, increasing the core density and thus the global SOL density. Similar results were obtained when puffing local gas close to the I-port antenna. Best performances were reached when puffing gas simultaneously at the valves close to the two antennas. Although increasing the gas puff rate further increases the coupling resistance, it should be noted that a gas puff rate larger than 11.4E20el/s could lead to possible arcing on the B-port antenna and potential plasma disruption. The latter is supposed to be caused by the low line-integrated density (3-4E19m^{-3}) in the core.

Simulations in parallel to the experiments were carried out. The edge plasma fluid and neutral particle transport code EMC3-EIRENE [14] was used to simulate the 3D scrape-off density in the presence of local gas puffing. The calculated density was then used in the antenna code RAPLICASOL [15, 16] to calculate the coupling resistances. A scan of gas puff rate was performed. Moreover, cases with different combinations of local gas valves were studied. The simulation results show good agreement with experiments, suggesting that injecting gas locally close to the antenna is a promising method to increase the ICRF power coupling.

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