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Scenarios integrated-analysis for standard single-null plasma of HL-2M

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Abstract:

The new tokamak HL-2M [1,2] at SWIP, is dedicated to study high-performance plasma physics and the edge/divertor physics by exploring various divertor concepts (e.g., snowflake, tripod), as well as the plasma-wall interaction. The high-power heating & current drive system (NBI of 15MW+ECW of 8MW+LHW of 4MW) allows the machine to gain the capability of studying a variety of operation scenarios. The plasma current can reach 2.5~3MA in the double-null configuration with high elongation of 1.8. Considering potential VDE risk, a single-null with the favorable vertical stability (elongation κ=1.5~1.6, minor radius a=0.64, triangularity δ=0.43) is desired in the first operation step. This paper focuses on the study of a standard single-null plasma, and two kinds of expected high-performance D-D scenarios (including the conventional inductive regime of Ip=1.8MA and the hybrid regime of Ip=1.4MA) are investigated, based on the integrated modelling suite—CRONOS [3-8]. For the conventional inductive H-mode regime of Ip=1.8MA / B_T=2.2T with the line-averaged density N_{bar} of $9.0\times10^{19}\,m^{-3}$ (Greenwald density fraction f_G=0.69), NBI of 15MW combining with ECW of 8MW are implemented. In such condition, the O-mode with the frequency of 105/140 GHz allows the EC wave propagates deeper than the X-mode in the plasma, obtaining the deposition peak around ρ=0.4-0.5. Meanwhile, the NBI deposition power on ions is ~4 times of that on electrons in the core, and the total NBI deposition power profile is flat within ρ=0.65. The non-inductive current fraction is 0.34 with the bootstrap current fraction of 0.29. Due to the very low off-axis additional current drive, the current profile gets peaked in the center with β_p=1.2. The thermal energy of the plasma reaches 2.0MJ with the high β_N of 3.0 which is seemed to be compatible with $l_i(3)$=0.9 of the peaked current profile for avoiding the resistive wall mode (RWM) instability. Similar to ITER baseline, the q_{95} can reach 3.0. For the hybrid regime of Ip=1.4MA / B_T=2.2T with Nbar=$4.9\times10^{19}m^{-3}$, NBI of 8MW combine with the equatorial ECW (X-mode + 105GHz) of 6MW and upper ECW (X-mode + 140GHz) of 2MW are implemented. In this case, power the deposition peak of NBI is on-axis, while the ECW deposition peak is off-axis. Comparing to the conventional inductive regime, both the bootstrap current fraction and the additional drive current fraction increase. The total non-inductive drive current fraction reaches 0.6. The substantial increased off-axis drive current allows the magnetic shear to get flat around the center. The center safety factor q_0 increases to 1.2 and the minimum safety factor q_{min} increases to 0.94 with the location of ρ=0.35. Such weak reversed shear leads to an internal transport barrier (ITB) generated around the center, allowing the energy confinement to increase. The $H_{98(y,2)}$ reaches 1.3. Similar to the ITER hybrid scenario, q_{95} in this regime reaches 3.9. The ion and the electron temperature of the center can reach 6.4keV and 8.5keV, respectively. The thermal energy of the plasma reaches 1.4MJ with the high β_N of 3.1.

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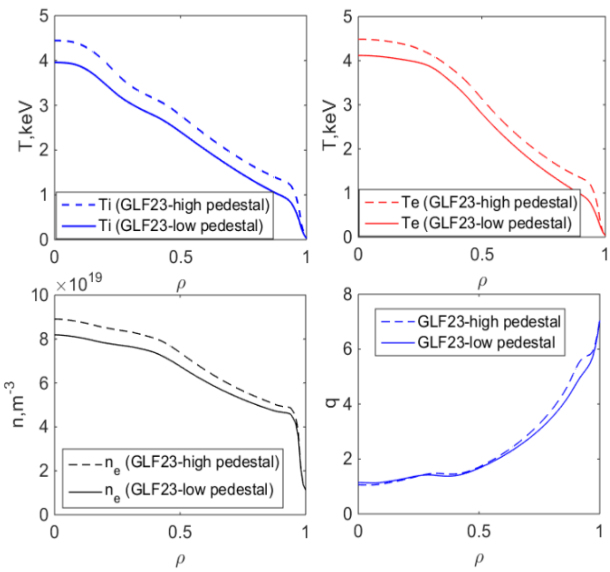

Figure 1 Profile (ion and electron temperature Ti, Te, density ne, safety factor q) comparisons between low(800eV) and high temperature pedestal (1300eV)