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+HLW 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 a=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 / Br=2.2T with the line-averaged density Nbar of 9.0 × 10^{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_p of 3.0 which is seemed to be compatible with Ip(3)=0.9 of the peaked current profile for avoiding the resistive wall mode (RWM) instability. Similar to ITER baseline, the q95 can reach 3.0. For the hybrid regime of Ip=1.4MA / Br=2.2T with Nbar=4.9×10^{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 q99 increases to 1.2 and the minimum safety factor q95 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_{ITB(2)} reaches 1.3. Similar to the ITER hybrid scenario, q95 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_p of 3.1.

References
[2] Li Q 2015 Fusion Engineering and Design 96-97 338

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