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Recent progress on divertor physics design of CFETR

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Since 2017, significant efforts have been made by Chinese community for the physics and engineering design of Chinese Fusion Engineering Testing Reactor (CFETR) [1], which is proposed to bridge the gap between ITER and DEMO. One of the key challenges is that the divertor solution for CFETR must meet requirements beyond that of ITER. For the standard CFETR operation with the fusion power up to 1 GW, the power across separatrix per unit major radius can reach 30 or 25 MW/m with respect to either fully non-inductive or hybrid mode operation, which are much higher than 17 MW/m for ITER. The high duty cycle of CFETR (0.3-0.5) requires negligible divertor target erosion rate and low enough heat loads that plasma-facing components are capable of withstanding. The divertor solution also needs to be compatible with high core fusion performance, which means low impurity contamination and efficient helium exhaust.

The design of divertor geometry has a strong correlation with the plasma configuration and also needs to meet the requirements of the first-wall and blanket. For the plasma current of 13.78 MA, the snowflake configuration could not be obtained since the current of divertor superconducting coil exceeds the engineering limits. Therefore, a lower single-null equilibrium based on the steady state scenario has been used for the divertor design. The configuration has a lower triangularity of 0.46 for a better divertor volume optimization. A conventional divertor configuration with long divertor legs (1.7 m for outer leg and 1.3 m for inner leg) and V-shaped design at the two target corners have been proposed for the referenced configuration. Since tungsten (W) will be used as the divertor armour material, extrinsic impurities need to be introduced as the main radiators to reduce the divertor heat loads. The stationary heat loads on divertor targets have been analyzed from simulations using the SOLPS code with seeding impurities neon (Ne) and Argon (Ar). With the same injection rate of 5×1020/s, the peak heat loads are reduced much lower than the limit and the total radiation power is similar for both impurities. However, Ne radiation mainly occurs within the divertor volume, and thus shows better compatibility with the core plasma. Although detachment is not obtained at the far SOL region, the low particle flux still leads to acceptable W erosion rate there.

In addition, an even longer divertor leg configuration (2.4 m for outer leg and 1.6 m for inner leg) and a small angle slot configuration (SAS) with normal leg lengths [2] have been studied in comparison to the referenced configurations. Both of the two configurations show better radiative abilities in the divertor for the same upstream conditions, and therefore, leads to lower heat flux and plasma temperature on the targets. Furthermore, BOUT++ has been used to simulate the ELMs behaviours, which helps to evaluate the transient heat loads on the divertor targets.

[1] G. Zhuang, et al., Nuclear Fusion 59 (2019) 112010

[2] H.Y. Guo et al., Nuclear Fusion 57 (2017) 044001

Country or International Organization

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