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Investigation of divertor operation for Japanese DEMO under low density SOL and large power exhaust of P_{sep}/R ~30 MW/m level

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Power exhaust scenario for the feasible DEMO plasmas and the divertor design have been studied with a high priority in the steady-state Japanese (JA) DEMO with the fusion power of 1.5 GW-level and the major radius of 8 m-class. The power exhaust concept requires large power handling in the SOL and divertor, i.e. P_{sep}~250 MW, and P_{sep}/R_p~30 MWm^{-1} corresponds to 1.8 times larger than ITER. Moreover, the SOL plasma density (n_e^{sep}) is expected to be relatively low, i.e. $2-3\mathrm{x}10^{19}\mathrm{m}^{-3}$, which corresponds to 1/3-1/2 of the pedestal density (n^{ped} ~$6\mathrm{x}10^{19}\mathrm{m}^{-3}$) since n^{ped} is restricted by the Greenwald density limit (n^{GW} = $6.6\mathrm{x}10^{19}\mathrm{m}^{-3}$). The long leg divertor (L_{div} = 1.6 m; 1.6 times longer than ITER) was proposed as a reference design. SONIC simulation with Ar impurity seeding demonstrated the peak heat load (q_{target}) on the outer target was reduced to less than 10 MWm^{-2} under the partially detached condition with the large radiation fraction of $f_{rad}^{sol+div}$ = $(P_{rad}^{sol}+P_{rad}^{div})/P_{sep}$ ~0.8.

Recently, operation of the plasma detachment and acceptable q_{target} ($\leq$10 MWm^{-2}) has been investigated under the severe conditions such as higher P_{sep} ~300 MW or lower $f_{rad}^{sol+div}$ ~0.7. The peak q_{target} was generally reduced with increasing n_e^{sep}, because the detached plasma width was decreased and the peak T_e^{div} and T_i^{div} at the attached plasma region were increased. The former case (higher P_{sep}) is acceptable in the expecting n_e^{sep} range of $2-3\mathrm{x}10^{19}\mathrm{m}^{-3}$, while the margin of the peak q_{target} is reduced. On the other hand, the latter case (lower $f_{rad}^{sol+div}$) requires operation in higher $n_e^{sep} > 2.3\mathrm{x}10^{19}\mathrm{m}^{-3}$. At the same time, the peak T_e^{div} and T_i^{div} were increased, which would enhance net erosion of the target. Investigation of the plasma diffusivity also started. Simulations with reducing both χ and D to half values, i.e. χ_e =χ_i = 0.5 $\mathrm{m}^2\mathrm{s}^{-1}$, D = 0.15 $\mathrm{m}^2\mathrm{s}^{-1}$, were performed for the three cases. Decay length of the parallel heat flux profile near the outer midplane separatrix ($\lambda_{q//}^{sol-OM}$) was decreased from the reference case (~1.9 mm), which is already narrow compared to 3.6 mm in the ITER simulation [2]. Peak q_{target} values were increased for all reduced χ and D cases, and the reference and higher P_{sep} cases were still acceptable, whereas higher n_e^{sep} was preferred. On the other hand, for the lower $f_{rad}^{sol+div}$ case, peak q_{target} $\leq$10 MWm^{-2} was not achieved in the operation range of the low n_e^{sep}. Changes in the characteristics of the q_{target}, T_e^{div} and T_i^{div} profiles in the partially detached divertor are summarized.

In addition, power exhaust scenario with impurity seeding other than Ar will be compared to the reference scenario. Effects of the divertor geometry (angles of target and reflectors, dome height) on the detached plasma will be discussed for the future design optimization with the particle exhaust.

[1] N. Asakura, et al., Nucl. Fusion 57 (2017) 126050.
[2] A. Kukushkin, et al., J. Nucl. Mater. 438 (2013) S203.

Country or International Organization

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