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# Simulation studies of He and particle exhaust in detached divertor for JA DEMO design

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SONIC divertor code enables simultaneous calculations of seeding impurity (Ar) and fusion product (He ash) transport. He exhaust has been investigated in JA DEMO, where exhaust power ($P_{out}$ = 250 MW), ion flux ($\Gamma^{D}_{out}$ = $1\text{x}10^{22}\text{s}^{-1}$) and He ion flux ($\Gamma^{He}_{out}$ =$5.3\text{x}10^{20}\text{s}^{-1}$, corresponding to 1.5 GW fusion power) were given at the core-edge boundary. Plasma diffusion coefficients of $\chi$ = 1 $\text{m}^2\text{s}^{-1}$ and $D$ (plasma and impurity ions) = 0.3 $\text{m}^2\text{s}^{-1}$ were the same as "standard"values in the ITER simulation. Peak heat loads at the inner and outer divertor targets were reduced less than 10 $\text{MWm}^{-2}$ for a reference series of the radiation fraction in the SOL and divertor, i.e. $f^{div}_{rad}$ = $(P^{sol}_{rad} + P^{div}_{rad})/P_{sep}$ ~0.8. He concentration ($c^{edge}_{He}$ = $n_{He}/n_i$) averaged at the plasma edge near the midplane ($r^{mid}/a_p$ = 0.96-0.98) was evaluated in the detached divertor condition; fully and partially detachment in the inner and outer divertors, respectively. $c^{edge}_{He}$ was reduced from 6 % to 4 % with increasing $n^{sep}_e$ from $1.8\text{x}10^{19}$ to $2.3\text{x}10^{19}\text{m}^{-3}$ by $\text{D}_2$ gas puff (keeping the same $f^{div}_{rad}$ ~0.8 by reducing Ar seeding rate), while the partial detachment was extended. In the divertor, in-out asymmetry of $c^{div}_{He}$ was seen (2-3 times); $c^{div}_{He}$ in the upstream of the inner divertor was enhanced to larger than 10 %, maybe caused by large thermal force (parallel ion temperature gradient) on He ions in the fully detached condition.The in-out asymmetry were reduced near the separatrix of the main SOL.

Influences of reducing $\chi$ and $D$ on the He exhaust were investigated ($\chi$ = 0.5, $D$ = 0.15 $\text{m}^2\text{s}^{-1}$), compared to above "standard"case. Radial gradient of the plasma density profile was increased particularly in SOL, and both $n^{sep}_i$ and $n^{sep}_e$ were increased from $1.6\text{x}10^{19}$ and $2.1\text{x}10^{19}\text{m}^{-3}$ to $2.4\text{x}10^{19}$ and $2.9\text{x}10^{19}\text{m}^{-3}$, respectively. Since $n^{sep}_{He} \sim 1\text{x}10^{18}\text{m}^{-3}$ and $n^{sep}_{Ar} \sim 2\text{x}10^{17}\text{m}^{-3}$ near the separatrix, $n^{sep}_e$ was ~25% larger than $n^{sep}_i$. Radial gradient of the temperature profile was increased near and inside the separatrixa. $c^{div}_{He}$ was increased to ~15% and ~10% in the inner and outer divertors, respectively. On the other hand, $c^{edge}_{He}$ = 7-9% was slightly increased. Since plasma performance such as $P_{fus}$ and $HH_{98y2}$ for the JA DEMO is based on system code results with $c_{He}$ = 7% in the main plasma, the plasma design is consistent with above simulation results, but it is necessary to avoid higher $c^{edge}_{He}$.

For the fuel particle exhaust, neutral and gas pressures ($P_{D0}$, $P_{D2}$) in the divertor were evaluated at exhaust slots of the dome and in the sub-divertor. For the "standard"case (without include neutral-neutral collisions, NNC), total neutral pressure ($P_D$ = $P_{D0}$ + $P_{D2}$) was increased from ~2 to ~3 Pa at the exhaust slots, and from ~1 to ~1.8 Pa in the sub-divertor, with increasing $\text{D}_2$ puff rate from $4.8\text{x}10^{22}$ to $9.6\text{x}10^{22}\text{D/s}^{-1}$. Effects of NNC on the particle exhaust and detachment are shown.

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